# 9

# Building a Smart Legal Ecosystem for Industry 5.0*

*Pompeu Casanovas*

This chapter introduces the problem of regulating human–robot interaction (HRI) according to the rule of law in the convergence of the Web of Data, the Internet of Things, and Industry 5.0. It explains some strategies fleshed out in the EU H2020 Project OPTIMAI, a data-driven platform for zero-defect manufacturing (ZDM) to deploy a smart industry ecosystem. The chapter defines the notions of *legal governance and smart legal ecosystems* as a mindset and as a toolkit to foster and regulate HRI in iterative cycles.

## 9.1 INTRODUCTION: INDUSTRY 5.0

This chapter introduces a new perspective for regulating *human–robot interaction* (HRI)[1] in the so-called *hybrid intelligence* (HI)[2] and *cyber-physical systems* (CPS)[3] on the Internet of Things (IoT) and Industry 5.0 (I5.0). The objective of this chapter is threefold: (i) to situate HRI into a smart manufacturing environment; (ii) to defend that HRI in such kind of environments (including the affordances of cobots and their dataflows) can only be coordinated, adjusted, and controlled through the regulation of the ecosystems in which they are found; and (iii) to suggest the notions of *Legal Governance* (LG) and *Smart Legal Ecosystem* (SLE), referring respectively to the way of regulating HRI in Industry 5.0, and to the mindset and regulatory toolkit for I5.0 and the IoT.

The term "Industry 4.0" (I4.0) stems from a project for advanced manufacturing, originally named *Industrie* 4.0, launched by the German government in 2011. Mechanization and steam power (I1.0), mass production and assembly line (I2.0), digitalization and automation (I3.0), and the decentralized production through shared facilities (I4.0) took place first and are assumed by the I5.0 approach. "Industry 4.0" refers to smart manufacturing. "Industry 5.0" refers to the

* *Optimizing Manufacturing Processes through Artificial Intelligence and Virtualization*, EU H2020 Project (2021–2023), Grant agreement ID: 958264. This chapter has benefited from the accurate reading and comments by Emma Teodoro Andrea Guillén, Mustafa Hashmi, Ho-Pun (Brian) Lam, Louis de Koker, Wendy Simon, Nikolaos Dimitrou, George Margetis, and Ugo Pagallo.

[1] I understand HRI as a specification of human–machine interaction (HMI), related to industrial, medical, or social robots.

[2] Akata, Z., Balliet, D., De Rijke, M., Dignum, F., Dignum, V., Eiben, G., Fokkens, A. et al., A Research Agenda for Hybrid Intelligence: Augmenting Human Intellect with Collaborative, Adaptive, Responsible, and Explainable Artificial Intelligence. *Computer* 53(08), 18–28, 2020.

[3] Xu, L. D. and Duan, L., Big Data for Cyber Physical Systems in Industry 4.0: A Survey. *Enterprise Information Systems* 13(2), 148–169, 2019.

human social effects and consequences of adopting smart manufacturing in the IoT, including ethical and legal values and compliance.

I5.0 links automation and the effective use of CPSs to the human dimension. Cyber-physical systems encompass sensor networks and embedded computing to monitor and control their environment, that is, they typically create *social ecosystems* in which both machine and human information processing must be stable and sustainable to be effective. Hence, the Internet of Things (IoT) technologies enable people and machines to create, collect, share, and transform data on an asynchronous and unparalleled scale, in real time and in continuous dataflows. It has revolutionized the way how business operates and has integrated into many facets of our lives, making us feel like we are *virtually connected* with each other. However, it is worth noting at this point that data can be automatically (or artificially) generated as *synthetic data* without human intervention or can be restrained from the use or "concealed" by service providers due to some unknown reasons.

The remainder of the chapter will be distributed into six sections. Section 9.2 briefly describes some regulatory issues of Industry 5.0 and the approach taken in this chapter. Section 9.3 focuses on the effective construction of OPTIMAI, a data-driven manufacturing platform. OPTIMAI constitutes an example of smart instrumentation of manufacturing production with AI-enabled sensors for quality inspection and monitoring, and it will help us to be focused on the problem. Section 9.4 describes the legal data governance system, specifically focusing on the manufacturing processes of Web 5.0 with augmented reality and digital twins. Section 9.5 elaborates on the notion of Smart Legal Ecosystem and its components. Section 9.6, finally, draws some conclusions and streamlines for future work.

## 9.2 INDUSTRY 5.0 AND SMART MANUFACTURING

This subject can be approached as "a future evolution designed to use the creativity of human experts working together with efficient, intelligent and accurate machines."[4] But it also embraces a holistic human perspective in which interactive processes of human/machine intelligence include not just technical and theoretical skills but also normative values and principles that can shape the environment in an interactive way.[5] This holistic perspective certainly entails many positive consequences as it reduces time and costs in rutinary work, facilitates a better cohesiveness of human–machine collaborations (in Connected Automated Vehicles, drones, cleaning devices, middleware systems…), and allows reaching complex goals in health, aging, and medical environments – for instance, improving surgery conditions, which is of utmost importance in medical practice.

However, as sword has two blades, the implementation of HRI might entail biases, side effects, and unattended harms as well, including the risks of facilitating cyberattacks and fostering the arms race. On top of that, manufacturing entails a cost/benefit ratio. Manufacturing processes occur in competitive markets; and this is fostering economic constraints on the implementation of normative solutions. It has been noticed that "in engineering teams and industrialists at

[4] Maddikunta, P. K. R., Pham, Q.-V., Prabadevi, B., Deepa, N., Dev, K., Gadekallu, T. R., Ruby, R., and Liyanage, M., Industry 5.0: A Survey on Enabling Technologies and Potential Applications. *Journal of Industrial Information Integration* 26, 100257, 2022.

[5] Tiwari, Saurabh, Prakash Chandra Bahuguna, and Jason Walker. Industry 5.0: A macroperspective approach. In *Handbook of Research on Innovative Management Using AI in Industry* 5.0, pp. 59–73. IGI Global, 2022.

large, ethical behaviour aspects of autonomous intelligent cyber-physical systems are often seen as an add-on."[6]

This matches our experience in industrial projects as well. The reluctance of the industry to implement ethical values is not based on moral grounds but on their cost and on the lack of widespread and common practices in this field. This, however, is changing at a rapid pace. Although it is better to sustain the proposals on economic arguments, there is an increasing trend to implement Industry 5.0 suggestions for the sake of higher efficiency, well-being, and personalization of labor.[7]

We could add another argument, which is of legal nature. In industry and corporate management, in addition to internal control objectives for improved performance, normative requirements usually stem from legal requirements, that is, constrictions that can be enforced and must be complied with to avoid fines and negative sanctions. The languages and tools of business and legal compliance emerged twenty years ago, mainly after the enactment of the Sarbanes-Oxley Act (2002), a US federal Act that expanded and created new requirements for all public company boards and accounting firms as a response to a few major corporate and accounting scandals (Enron, Arthur Andersen, WorldCom, among them). It also fueled the development of the ISO/IEC 27000 series-standards on information security, cybersecurity, and privacy protection published by the International Organization for Standardization (ISO) and by the International Electrotechnical Commission (IEC).[8] Hence, ethical behavior was fostered by the legal framework set with the aid of specific legislative measures, procedures, and standards.

According to this background and within these premises in mind, it would be easy to draw the conclusion that morals, ethics, and law matter and should be carefully tailored to fit into the new scenarios set by Industry 4.0 and 5.0 – to shape, control, and monitor the technological developments. From this perspective, the questions could be: How can CPSs be regulated? How could we make sure that the protections of the *rule of law* are applied and fairly used to enhance rights and enforce duties for all stakeholders through Artificial Intelligence (AI) devices and IoT technologies? How could citizens, consumers, disabled people, and vulnerable communities be better supported and protected?

These are the objectives willingly pursued by the recent legislative work on AI and law both in Common Law and Civil Law cultures, and there is a general agreement about their benefits. Nevertheless, the devil is in the details. Legal instruments do not operate in the I4.0 and I5.0 era as they did in the past. Cyber-physical systems change and adjust not just technology and human–machine interactions but also the regulatory tools and the way regulation should be understood and implemented. Ecosystems in I4.0 – *Smart Industry Ecosystems* (SIE), based on CPS – are under construction and still need to overcome some hurdles.[9] The use of AI for

[6] Trentesaux, Damien and Stamatis Karnouskos. "Ethical behaviour aspects of autonomous intelligent cyber-physical systems." In Service Oriented, Holonic and Multi-agent Manufacturing Systems for Industry of the Future: Proceedings of SOHOMA 2019 9, pp. 55–71. Springer International Publishing, 2020.

[7] Murphy, C., Carew, P. J., and Stapleton, L., Ethical Personalisation and Control Systems for Smart Human-Centred Industry 5.0 Applications. *IFAC-PapersOnLine* 55(39), 24–29, 2022.

[8] According to ISO/IEC 27002: "The organization must identify and document its obligations to external authorities and other third parties in relation to information security, including intellectual property, [business] records, privacy/personally identifiable information and cryptography."

[9] "Digital transformation has been slowed by legacy business practices and market drivers that have increased implementation complexity. Furthermore, potential benefits that can be derived from collected and transmitted data are largely untapped. These actions have widened the gap between small and medium-sized manufacturers (SMMs) and large manufacturers, and have failed to capture the greatest, available benefits from factory implementation that

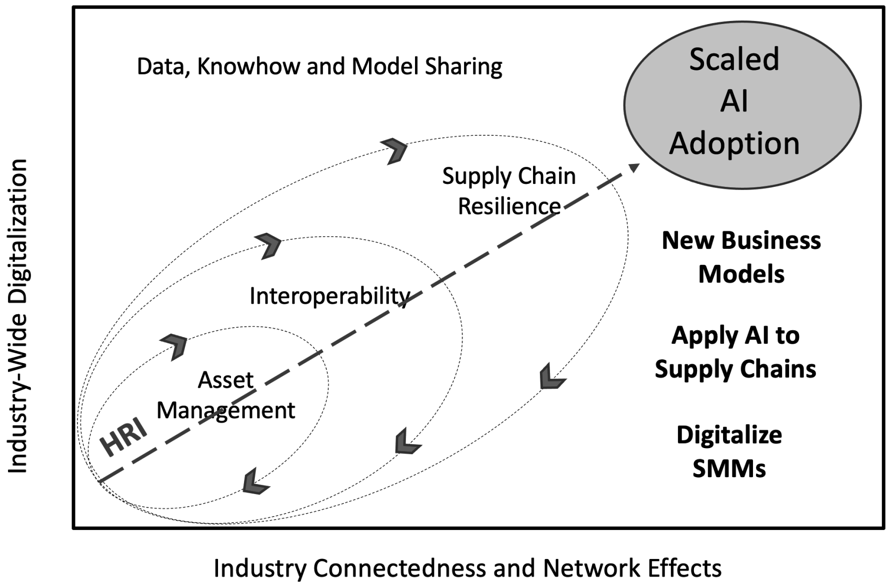


FIGURE 9.1 *Smart Industry Ecosystems*. NIST general framework for Resilient Manufacturing Ecosystems through AI.
Source: Adapted from NIST (2022). SMMs stands for Small- and Medium-sized Manufacturers.

greater industry-wide interoperability, supply chain resiliency, new business models, and environmental sustainability requires "industry-wide strategies for 'data sharing' (in many forms) and collaborative application development to broaden access, lower cost, and speed up industry adoption of AI on the factory floor." There is a need "for networked intercompany operations that optimize supply chains, address resiliency, enable new business models, and open new revenue sources" (NIST AMS 100-47, September 2022).

Human–robot interaction can be situated into this general framework settled by the National Institute of Standards and Technology (NIST) for manufacturing ecosystems. Figure 9.1 depicts the broad NIST landscape for Resilient Manufacturing Ecosystems, where HRI crosses diametrically the different layers of AI adoption for SIE.

Thus, the problem we are facing can be paraphrased as follows: *What are the conceptual and technical requirements that should be considered to model, put in place, and eventually implement the Smart Legal Ecosystems (SLE) that could be (partially) encapsulated into CPS and SIE? What should an SLE consist of?*

An SLE cannot be confused with the abstract normative representation of a regulatory model. It refers to the dynamic legal conditions, processing requirements, and social impact of computing infrastructures and dataflows in platform-driven economies. Thus, regulatory models that are embedded into CPS shape the working framework for the interactions between human and artificial agents in an indirect way, as ecosystems *emerge* from them in a nonlinear way, and they must be accepted and collectively enacted to become stable,

are the result of integrating across supply chains and ecosystems." NIST (2022), *Towards Resilient Manufacturing Ecosystems Through Artificial Intelligence – Symposium Report*. (National Institute of Standards and Technology, Gaithersburg, MD), NIST Advanced Manufacturing Series (AMS) NIST AMS 100-47, September 2022, https://doi.org/10.6028/NIST.AMS.100-47 sustainable, and effective. They are not originated from top-down regulatory processes but from a set of complex social conditions that spread across different levels of hierarchy in machine–human autonomy and decision-making. Evolving social contexts encompass several dimensions and layers to be regulated, fostering the emergence of social environments in which normative multiagent systems (norMAS), humans, and context-aware machinery (such as IoT devices) can be coordinated to produce compliance effects in real time. The resulting intelligent, *hybrid*, social systems are also able to produce a data governance effect in real time. Norms, principles, policies, and best practices can be partially modelled. Ethical values embedded into design are key in this process, playing a balancing role and becoming door hinges of the whole regulatory system.

## 9.3 OPTIMAI

### 9.3.1 *OPTIMAI Overview*

OPTIMAI – *Optimising Manufacturing Processes through Artificial Intelligence and Virtualization*[10] – is an ongoing I4.0 EU H2020 project, lasting from 2021 to 2023. It aims to create a “European industry ecosystem” focused on optimizing production, reducing defects, and improving training for the so-called zero-defect manufacturing (ZDM). As stated by Tzovaras, “in Industrial Engineering, there is a common saying that you need to choose two out of three between a cheap, reliable, or fast production. That captures the trade-off between production time, quality, resources and performance of a manufacturing procedure.”[11] Some developing solutions include: (i) A multimodal sensor network allowing for smart, secure data collection on production lines, (ii) AI methodologies to allow for the early detection of defects in the manufacturing chain, (iii) an intelligent marketplace for the profiling, indexing, and repurposing of defective parts, (iv) digital twinning technologies to allow for the virtualization of the production process, and (v) a context-aware augmented reality environment using AR glasses to optimize production.[12]

To create the architecture for the OPTIMAI platform, many guidelines and preconceived plans and methodologies are followed, according to the recommendations, standards, protocols, and best practices developed by the ISO,[13] IEC,[14] World Wide Web Consortium (W3C),[15] Institute of Electrical and Electronics Engineers (IEEE),[16] and the more recent German Platform Industrie 4.0[17] and Industry IoT Consortium (IIC).[18]

OPTIMAI architecture is aligned with the models incepted by both consortia, the Reference Architectural Model Industrie 4.0 (RAMI 4.0) and the Industrial Internet Reference Architecture (IIRA). RAMI 4.0 is a three-dimensional design to map the deployment of Industry 4.0 functionalities, allowing all stakeholders to connect and discuss in a structured manner (Schweichhart 2016). As Margetis et al. contend, RAMI 4.0 “is one the oldest attempts at building a universal understanding of I4.0, with the intent to propose standards, define a common language, and

[10] OPTIMAI, https://cordis.europa.eu/project/id/958264
[11] Tzovaras, Dimitrios, “Short Project Overview” (presentation), OPTIMAI Kick-off Meeting, 3 and February 4, 2021.
[12] https://optimai.eu/
[13] www.iso.org/home.html
[14] https://iec.ch/homepage
[15] www.w3.org/
[16] www.ieee.org/
[17] www.plattform-i40.de/IP/Navigation/EN/Home/home.html
[18] www.iiconsortium.org

indicate rules for describing requirements and structures for the design of smart factories in different use cases."[19] IIRA consists of a common architecture framework to develop interoperable IoT systems (IIoT) and common data modelling for the integration of devices into Industry 4.0 networks. Although there are some differences between the two models, for instance regarding the definition of the so-called I4.0 components, they are deemed to be compatible and interoperable.[20] Hence, the OPTIMAI architecture has been aligned with both "so as to substantiate it as an I4.0-compliant approach to zero-defect manufacturing."[21]

It is worth mentioning that the architecture includes the vertical and horizontal dimensions, axes, and layers of smart manufacturing, in which smart sensors and actuators are interconnected and integrated into industrial systems using the technologies developed for the IoT and CPS.[22] On one hand, RMI 4.0 axes refer to (i) the *hierarchy levels* of automation (layers: product, field device, control device, station, work centers, enterprise, connected world); (ii) *lifecycle* of systems and products and value stream, including both development and maintenance (lifespan of a relevant object: a product, a machine, documentation, etc.); and (iii) *I4.0 components* (asset, integration, communication, information, functional, and business layers).[23] On the other hand, the US IIRA reference model specifies four layers or "viewpoints" that the industrial system should address independently of the manufacturing field at stake. Namely, (i) *business* requirements, for example, return on investment; (ii) *usage* (expected usage of the system based on business requirements); (iii) *functional* components and interactions, roles and responsibilities; and (iv) *implementation* of the functional blocks (connectivity communication protocols, deployment considerations, etc.).

Figure 9.2 shows the layered structure of RAMI 4.0 and how the OPTIMAI architecture fits into it. The OPTIMAI architecture is mapped onto the 2D layer-and-hierarchy slice.

### 9.3.2 *OPTIMAI Construction Layers*

Within the framework drawn in Figure 9.1, OPTIMAI created three use cases to be evaluated: (i) Reducing the number of quality defects in the production line ("Zero defect quality inspection"); (ii) improving the efficiency of the production line by optimally calibrating machines/robotic cells in a way that decreases stoppages ("Production line setup-calibration"); and (iii) optimizing the production of the manufacturing line by means of a digital twin where

[19] Margetis, George, Konstantinos C. Apostolakis, Nikolaos Dimitriou, Dimitrios Tzovaras, and Constantine Stephanidis. Aligning Emerging Technologies onto I4. 0 principles: Towards a Novel Architecture for Zero-defect Manufacturing. In *2022 IEEE 27th International Conference on Emerging Technologies and Factory Automation (ETFA)*, pp. 1–8. IEEE, 2022.

[20] Pribiš, R., Beňo, L., and Drahoš, P., Asset Administration Shell Design Methodology using Embedded OPC Unified Architecture Server. *Electronics* 10(20), 2520, 2021.

[21] Apostolakis, Konstantinos C., George Margetis, with co-authors Stefania Stamou, Nikolaos Dimitriou, Christina Tsita, Walter Domenico Vergara, Manfredi Giuseppe Pistone, George Bogdos, George Alexiou, Andreas Böttinger, Ali Sadr, Elpiniki Papageorgiou, Theodosis Theodosiou, Andrea Gomez, Clara Valero, Antonio Zanesco, Greg Tinker, Fernando Ubis, Agata Gurzawska, D2.5: The OPTIMAI architecture specifications – 2nd version, Optimizing Manufacturing Processes through Artificial Intelligence and Virtualization, EU H2020 Project, 30 June (2022).

[22] Xu, H., Yu, W., Griffith, D., and Golmie, N., A Survey on Industrial Internet of Things: A Cyber-Physical Systems Perspective. *IEEE Access* 6, 78238–78259, 2018; Xu and Duan (2019).

[23] Apostolakis, Konstantinos C., Dimitrios Arampatzis, George Margetis, with Co-authors Christina Tsita, George Bogdos, Andreas Böttinger, Fernando Ubis, Elpiniki Papageorgiou, Sabrina Verardi, Manfredi Giuseppe Pistone, Andrea Gomez, Andrea Guillén, Emma Teodoro, Paul Hayes, and Agata Gurzawska. D2.4: The OPTIMAI architecture specifications – 1st version, Optimizing Manufacturing Processes through Artificial Intelligence and Virtualization, EU H2020 Project, 28 December (2021), pp. 21–22.

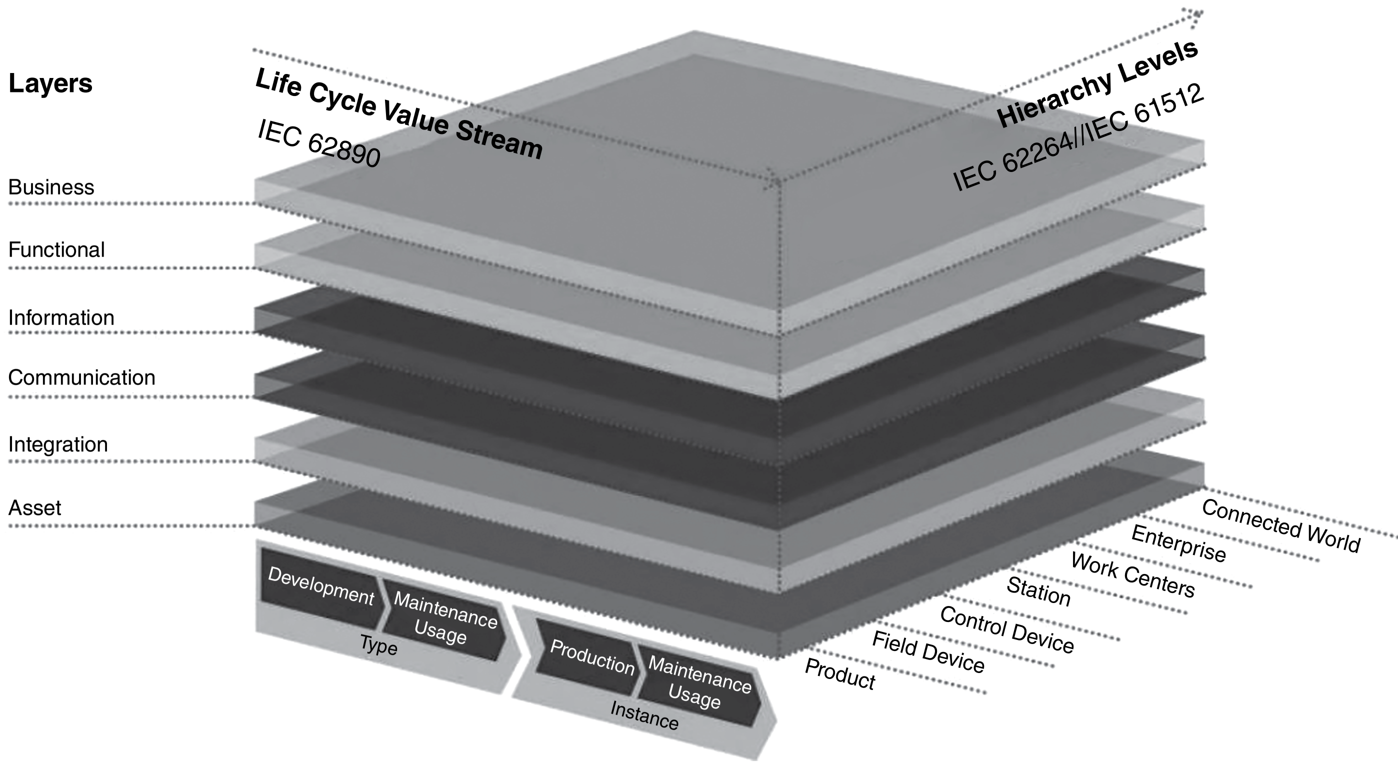


FIGURE 9.2 OPTIMAI placement within the RAMI 4.0 cubic model. Adapted from the original Graphic © Plattform Industrie 4.0 and ZVEI, and retrieved from Plattform Industrie 4.0 (2018). Source: Apostolakis, Arampatzis, and Margetis et al. (2021, 2022).

optimal product manufacturing sequence can be calculated for future planning purposes ("Production planning").

These processes are created inside the "Instance" phase of the Life Cycle and Value Stream axis. They fall within the "Production" state, "as the actions undertaken to deal with quality issues during manufacturing execution and formulating knowledge for ideally setting up the manufacturing environment." OPTIMAI defines components across all Layers and Hierarchy Levels for the "Production" state of the "Instance" Life Cycle & Value Stream Phase, following the whole iterative processes, including (i) the collection of data and actions based on calculated parameters; (ii) the Middleware Subsystem; (iii) the Middleware Data Cloud Repository; (iv) the Blockchain Subsystem; (v) the Operator-Machine Interaction & Decision Support Back-End components (OMIDES); (vi) the Intelligent Marketplace components comprised by the Back-End and Customer Front-End applications, providing a connection between the factory and the outside world (third parties); (vii) the Digital Twinning subsystem components; (viii) simulation services; and (ix) Smart Quality Control components. As said, the thirty-eight functional blocks of the architecture are also aligned with the IIRA viewpoints, as IIRA and RAMI 4.0 support service-oriented architectures (SOA) and decompose system functionality into an array of interconnected services.

Figure 9.3 shows the alignment of OPTIMAI, following the design offered by the *Industrial Internet Consortium and Platform Industrie 4.0 Joint Whitepaper*.[24] Margetis et al. (2022) explain this alignment in detail.[25] In Figure 9.3 (rectangle), AIF1 stands for Analysis for Defect detection/prediction; AIF2: DT Simulation models; AIF3: DT Simulation Engine; AIEP: AI Edge Processing Services; BC1: Firmware/Software Validation Service; BC2: Access Control Services; BC3: Data Integration Service; CDR: Cloud Data Repository; MW: Middleware; OM1: Interpretation and Visualization; OM2: Production (re)configuration; QCS: Quality Control Sensors Network; UA1: OMIDES Front-end; and UA2: Simulation Front-end.[26]

This functional mapping (Figure 9.3) shows the following features: (i) *Physical systems* are directly mapped onto the RAMI 4.0 Assets Layer, and are understood as the physical resources on the factory shop floor (e.g., smart sensor, smart glass, and human agent), (ii) the *Control Domain* includes components, whose functions deal mainly with the control, sensing, and action on the physical systems (sensing, actuation, communication, entity abstraction, asset management, and executor), (iii) the *Operations domain* exercises monitoring, management, and control over the assets in the Control domain, dealing with operations regarding decision-making based on data capturing, processing, and validation, and identifying several functions directly mapped (provisioning and deployment, asset management, monitoring and diagnostics, prognostics, and optimization), (iv) the *Application domain* deals with functions that support application-specific logic (logics and rules, APIs, and UI), and (v) the *Business domain* deals with functions that implement business processes and maps directly onto the RAMI 4.0 Business Layer.[27]

[24] Lin, S.-W., Murphy, B., Clauer, E., Loewen, U., Neubert, R., Bachmann, G., Pai, M., and Hankel, M. *Architecture Alignment and Interoperability: An Industrial Internet Consortium and Plattform Industrie 4.0 Joint Whitepaper* [White paper]. Industrial Internet Consortium, 2017. Available at URL: www.iiconsortium.org/pdf/JTG2_Whitepaper_final_20171205.pdf

[25] Margetis, George, Konstantinos C. Apostolakis, Nikolaos Dimitriou, Dimitrios Tzovaras, and Constantine Stephanidis, Towards a Novel Architecture for Zero-defect Manufacturing, 2022.

[26] Cfr. Margetis et al., 2022, ibid.

[27] Apostolakis, Margetis et al., 2022, pp. 55–59.

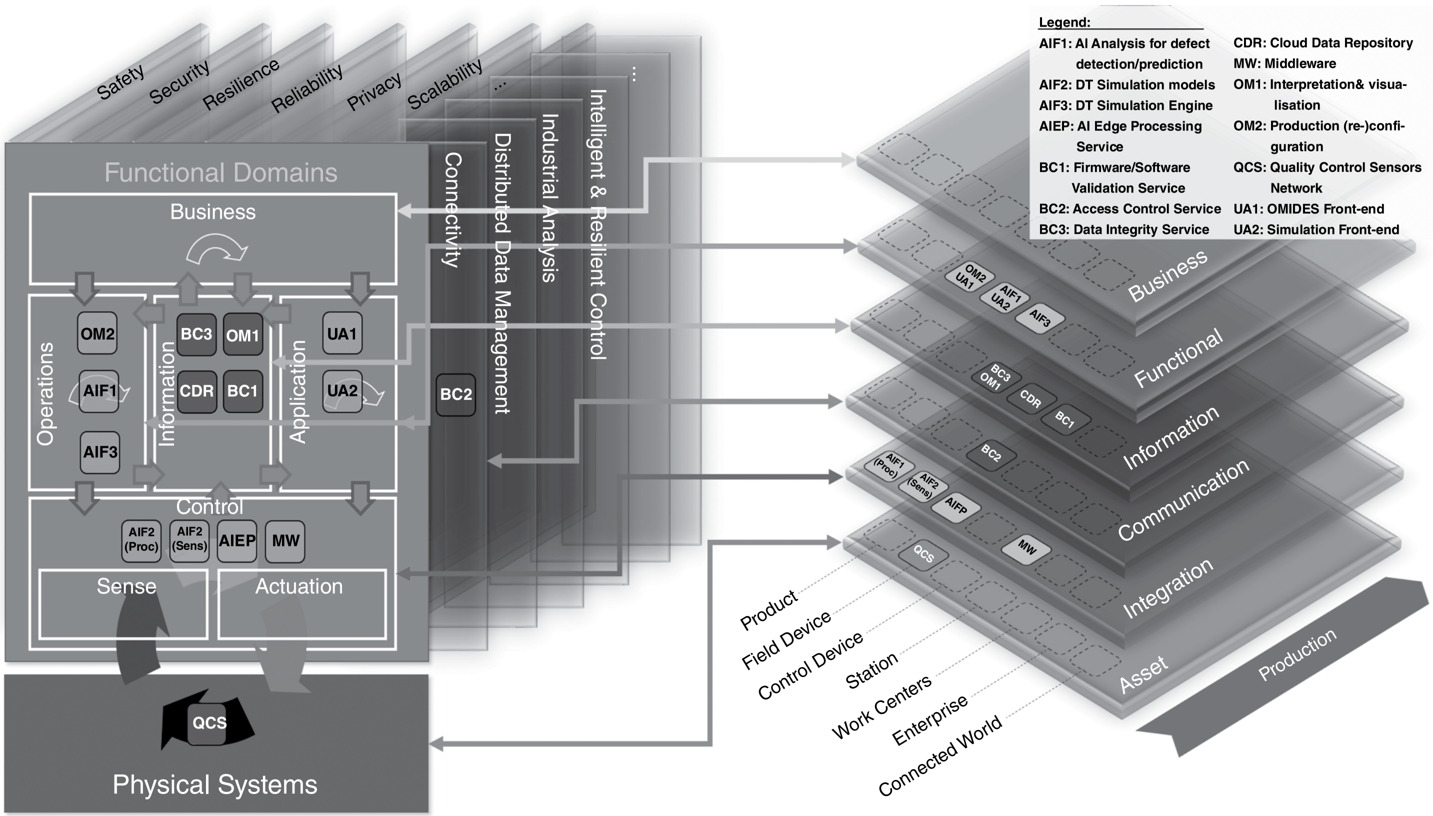


FIGURE 9.3 Functional mapping of the OPTIMAI Architecture into IIRA, based on the alignment to RAMI 4.0.
Source: Apostolakis, Arampatzis, and Margetis et al. (2021) and Apostolakis, Margetis, et al. (2022). Vertical layers in the oblique rectangle include *Safety*, *Security*, *Resilience*, *Reliability*, *Privacy*, *and Scalability* (although the property of scalability falls out of the regulatory scope, it has regulatory effects).

### 9.3.3 *OPTIMAI Regulatory Topology*

The final OPTIMAI topology of the architecture is shown in Figure 9.4.

A "smart factory" refers to the vertical integration of various components to implement a flexible and reconfigurable manufacturing system. This is one of the key features of the I4.0. OPTIMAI design that follows the Wang et al. (2016) model,[28] according to which the smart factory framework consists of a *self-organized multiagent system* assisted with big data-based feedback and coordination. The model includes an intelligent negotiation mechanism for agents to cooperate with each other. Thus, Figure 9.4 shows the organization of components in the different layers, and their relation to the operational mechanism dual loop closed system: (i) The first loop consists of elements that are involved in the coordination and feedback provided at the Cloud level toward reconfiguring assets found in the Physical Resources Layer ("Coordinator"), (ii) the second one regards data visualization and manipulation manifested between the Cloud components engaged in statistical analysis ("Statistician") and the supervisory terminal applications. Big data storage on the Cloud facilitates both sensing and acting, as well as control manipulation processes in the smart factory framework.[29]

### 9.3.4 *OPTIMAI Conceptual Architecture*

Figure 9.5 draws the main components of the conceptual architecture. Its building blocks can be summarized as follows: (i) Quality Control Sensor Network, (ii) Middleware, (iii) Machine-Operator Interface, (iv) Data Repository, (v) Blockchain, (vi) Intelligent Marketplace, (vii) Digital Twins, (viii) Production Optimization, (ix) Smart Quality Control, and (x) Visualization and Decision Support.

Components are organized into modules that coordinate the information flows on the platform. Thus, the OPTIMAI concept can be divided into different sets of tasks: (i) Instrumentation of production line with smart sensors; (ii) Real-time monitoring and data collection employing a middleware layer; (iii) Using AI methods to detect defects early in production; (iv) Virtualization of the manufacturing process using digital twins; (v) Speed up line qualification and reconfiguration utilizing a context-aware augmented reality environment.

Margetis et al. (2022) describe OPTIMAI architecture as follows:

> The OPTIMAI service-oriented architecture (SOA) stack segments the envisioned ICT subsystems on a vertical axis, thus allowing for a high-level classification of different technological enablers on the grounds of their properties, relationships, and execution environment. Each layer thus comprises a major subsystem, with information flowing through the overall system from top (i.e., the IoT sensing devices) to the bottom (i.e., the actual UI/HMI software). The involved subsystems are: (i) the *Quality Control Sensors Network*; (ii) the *Edge Computing Modules*; (iii) the *Cloud Computing Modules*; and (iv) the *Users' Applications*.[30]

[28] Wang, S., Wan, J., Zhang, D., Li, D., and Zhang, C., Towards Smart Factory for Industry 4.0: A Self-organized Multi-agent System with Big Data-based Feedback and Coordination. *Computer Networks* 101, 158–168, 2016.

[29] Apostolakis, Margetis et al. (2022), pp. 75 and ff.

[30] Margetis, George, Konstantinos C. Apostolakis, Nikolaos Dimitriou, Dimitrios Tzovaras, and Constantine Stephanidis, 2022.

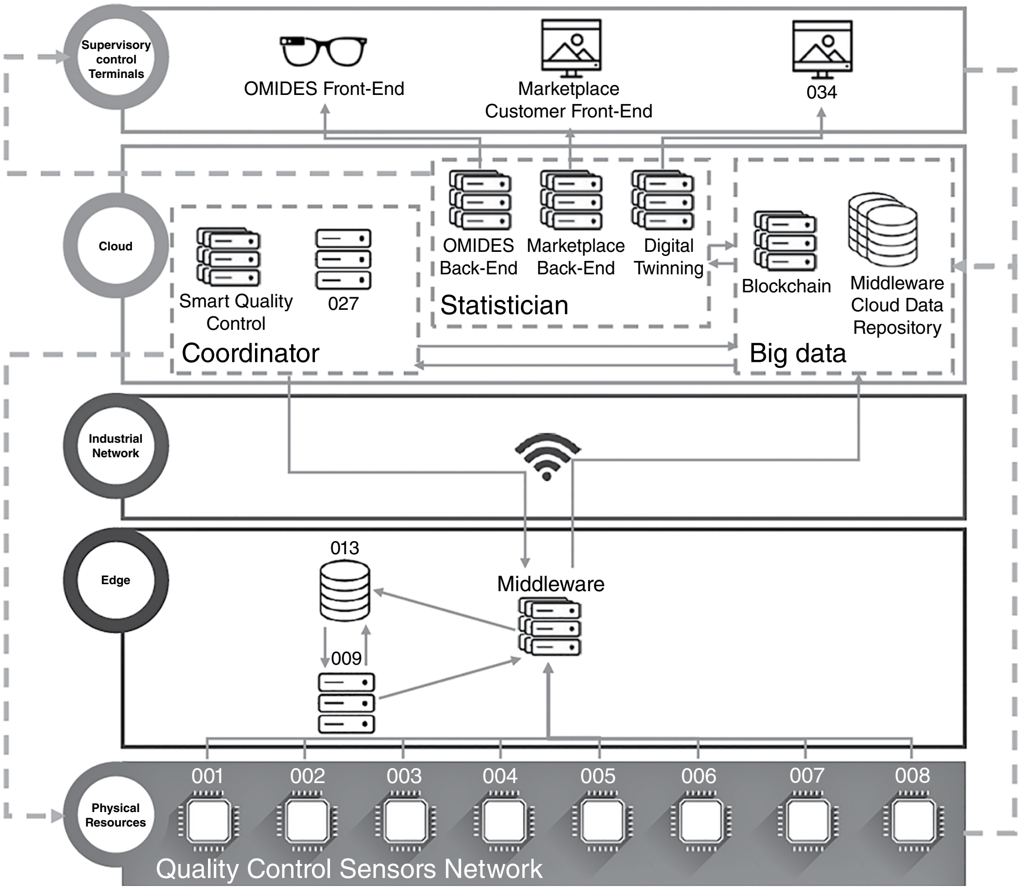


FIGURE 9.4 Topological view of OPTIMAI architecture through the Smart Factory framework perspective.
Source: Apostolakis, Margetis, et al. (2022, 78).

### 9.3.5 *Augmented Reality, Digital Twins, Smart Glasses*

Let's focus now on the elements and technologies developed through HRI. *Digital twins* reflect physical objects, processes, or systems. There are different definitions.[31] Perhaps the simplest is the following one: "a virtual construct that represents a physical counterpart, integrates several data inputs with the aim of data handling and processing, and provides a bi-directional data linkage between the virtual world and the physical one."[32] *Augmented reality* can be understood as an interactive experience that combines the real world and computer-generated content, fostering HRIs. *Smart glasses* "are a new wearable augmented reality (AR) device that captures and processes a user's physical environment and augments it with virtual elements."[33] All three technologies are implemented in the project.

[31] van der Valk, H., Haße, H., Möller, F., and Otto, B., Archetypes of Digital Twins. *Business & Information Systems Engineering* 64, 375–391, 2022.
[32] Van der Valk et al., p. 377.
[33] Rauschnabel, P. A., Babin, B. J., Claudia tom Dieck, M., Krey, N., and Jung, T., What Is Augmented Reality Marketing? Its Definition, Complexity, and Future. *Journal of Business Research* 142, 1140–1150, 1140, 2022.

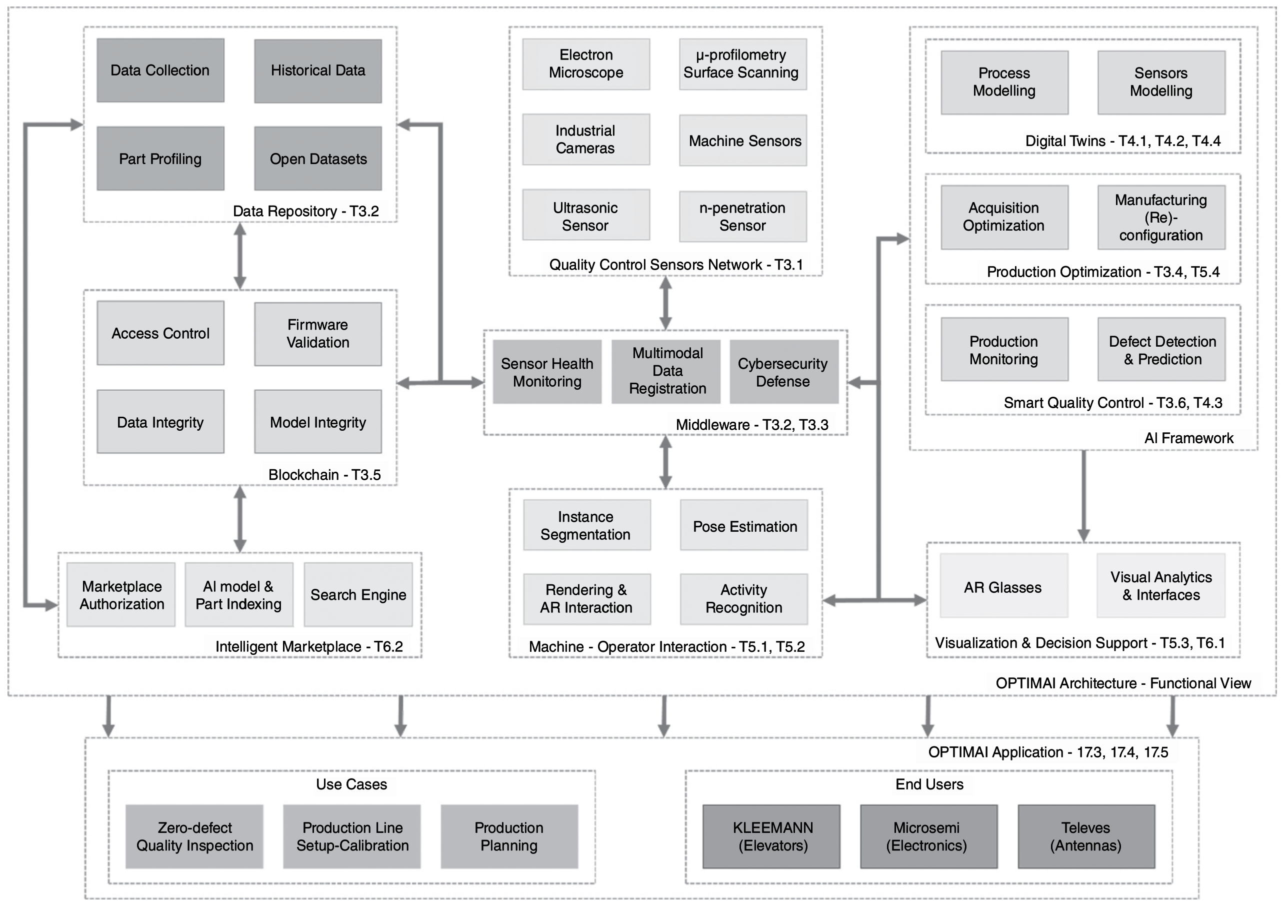


FIGURE 9.5 OPTIMAI Conceptual Architecture Diagram.
Source: Apostolakis, Margetis, et al. (2022, 75; latest version, 2023).

OPTIMAI is carrying out three industrial pilots and twenty-four *modules* or *technical components* in three areas: (i) quality inspection; (ii) production line set-up/calibration; and (iii) production planning.[34] The first one quantifies efficiency losses in the manufacturing process using OEE (Overall Equipment Effectiveness) metrics. This indicator can be segmented into three parameters (availability, performance, and quality). The digital twin of an antenna manufacturing plant allows simulating production scenarios. The second pilot refers to electronic component assembly. This is a complex process that requires several steps. Many of them have rejection criteria being classed as nonrecoverable (i.e., wafer sawing, routing, and encapsulation). A quick response to defect detection with automatic and semiautomatic recalibrations, considering operators' experience and their ability to react can be facilitated with augmented reality interfaces. In the third pilot, digital twins of hydraulic power units are combined with AI models that map design choices to the unit's performance and any related defects. These models are trained based on the data collected from the test lab and they focus on repeated errors and defects.

Human–robot interaction occurs with specific features in each one of the pilots and use cases in different scenarios. It is worth mentioning that what is crucial at the micro level is *situated cognition*, that is, experience, the *personal*, *local*, and *situated knowledge* of the human being interacting with the system and performing the manufacturing work.

## 9.4 LEGAL GOVERNANCE

### 9.4.1 *Cloud Robotics and HRI*

How can HRI be regulated in a complex HI environment? What are their main elements? And how to ensure the resulting regulatory system is *legal*, that is, compliant with the law?

The OPTIMAI project illustrates the ethical and legal challenges that are faced in cloud robotics and smart manufacturing. This is an increasingly relevant issue, due to its incremental value. According to some estimations, the global robot market shows an average yearly growth of 30 percent and forecasts the demand will reach USD 209 billion by 2025.[35] Some reports contend that 1 billion devices are expected to connect to the Internet by 2025 and that the cloud robotics market will be valued at USD 9822.8 million by 2024.[36] Although, according to NIST, "at present, the most successful use cases for AI in manufacturing are heroic efforts that require advanced education and training, and these efforts do not scale to other equipment, facilities, or companies."[37]

Cloud robotics is a notion that bridges I4.0 and I5.0.[38] It refers to "the evolution of conventional robotics technology towards the integration of cloud technologies."[39] If a robot is deemed

[34] For a detailed description of the pilots and use cases, cfr. Mastos, Theofilos, Co-authors: Emma Teodoro, Andrea Guillén, Agata Gurzawska, Paul Hayes, George Margetis, Stavroula Ntoa. D2.1 User and Ethics and Legal Requirements. First Version., Optimizing Manufacturing Processes through Artificial Intelligence and Virtualization, OPTIMAI, EU H2020 Project, 30 June (2021). This section briefly summarizes them.

[35] Siriweera, A. and Naruse, K., Survey on Cloud Robotics Architecture and Model-driven Reference Architecture for Decentralized Multicloud Heterogeneous-Robotics Platform. *IEEE Access* 9, 40521–40539, 2021.

[36] Dawarka, V. and Bekaroo, G., Building and Evaluating Cloud Robotic Systems: A Systematic Review. *Robotics and Computer-Integrated Manufacturing* 73, 102240, 2022.

[37] NIST (2022), p. 3.

[38] Fosch-Villaronga and Millard provide a short glossary that clarify the usage of terms. They differentiate cloud computing from cloud robotics and CPS. Compare Fosch-Villaronga, E. and Millard, C., Cloud Robotics Law and Regulation: Challenges in the Governance of Complex and Dynamic Cyber–physical Ecosystems. *Robotics and Autonomous Systems* 119, 77–91, 87, 2019.

[39] Dawarka and Bekaroo (2022), p. 102240.

to be a programmed machine that has the capabilities of performing complex tasks automatically, and the cloud is defined as a set of network-enabled services, providing scalable and accessible computing platforms on demand, cloud robotics "is an upcoming tendency to turn robots into more intelligent and robust units through cloud integration."[40] Coupling robotics to the cloud entails the integration of quite diverse technologies, from big data management to blockchain to sensor networks and to access control or remote keyless entry (for instance, in connected autonomous vehicles). In addition, I4.0 proposes the use of *collaborative robots*, "cobots," cooperating with humans.[41]

The OPTIMAI design of latency-sensitive, data-heavy, and computationally intensive I4.0 technologies shares these features. They have been aligned with the aims of Industry 5.0, that is, fostering well-being and adopting a human-in-the-loop modelling.

### 9.4.2 *Top-Down/Bottom-Up Approach*

OPTIMAI's epistemic approaches are designed from an engineering point of view. Its architecture and specifications follow the following pattern. First, a *top-down* approach, in which the general design is based on a common understanding of the final system behavior and functionalities – that is, the *requirements usage scenarios* – and outlines the role and functionality of subsystems and components. Second, *a bottom-up specification*, the detailed specification of all individual elements of the system, with the identification of existing components, connecting them to refine, and eventually give its final form to the overall architecture. This entails an expert community-based trial and error perspective, in which all stakeholders, including final users and the companies holding the pilot test beds and sandboxes can participate to refine the technological outcomes. It is in accordance with a streamline of *functional*, *information*, *and deployment* view that is commonly followed to build Platform-as-a-Service (PaaS) and Robot-as-a-Service (RaaS) systems.

Going along with this approach, several ethical and legal requirements were thoroughly identified and built in as guidelines to be implemented into the system. This is a procedure with many advantages, as it offers the possibility of avoiding blind alleys and redressing side effects beforehand. Requirements can be grouped into *functional* and *nonfunctional* requirements. The former ones describe what the system should do, whereas the latter are grouped into Key Performance Indicators (KPIs), ethics, legal, operational performance, and potential technology innovation requirements. In addition to them, (i) internal and external risk analyses and mitigation procedures (ethical, legal, and societal) are usually put in place, (ii) Privacy and Data Protections Impact Assessments (PIA, DPIA); Societal Impact Assessment (SIA); and Ethical, Legal, and Societal Risks Assessments (ELS RA) are commonly performed.[42]

40 Notice that for the purposes of this chapter I do not need to add the requirement of being movable to the degree of autonomy that robots usually have, narrowing down the definition of what "robots" are deemed to be. ISO 8373:2012 definition points that a robot is an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, *which may be either fixed in place or mobile* for use in industrial automation applications.

41 Velásquez Villagrán, Nancy, Patricia Pesado, and Elsa Estevez. "Cloud Robotics for Industry 4.0-A Literature Review." In Cloud Computing, Big Data & Emerging Topics: 8th Conference, JCC-BD&ET 2020, La Plata, Argentina, September 8–10, 2020, Proceedings 8, pp. 3–15. Springer International Publishing, 2020. Prassida, G. F. and Asfari, U., A Conceptual Model for the Acceptance of Collaborative Robots in Industry 5.0. *Procedia Computer Science* 197, 61–67, 2022.

42 All these instruments were extensively deployed in OPTIMAI, cfr. Mastos et al. (2021), Hayes and Gurzawska et al. (2021), Teodoro and Guillén (2021), and Casanovas et al. (2022).

However, recent literature on CPS has pointed out the missing link between the bidirectional planning approach and cloud robotics. Fosch-Villaronga and Heldeweg have suggested that "what lacks in robot governance is actually a backstep mechanism that can coordinate and align robot and regulatory developers."[43] They contend that the mere creation of coordinating agencies risk being largely ineffective, hence, they envision that automation of the communication process between the robot developers and the regulatory bodies can resolve such issues, as offering better solutions to the regulatory problems. There are some added issues, mainly legal uncertainty, ambiguity, and fragmentation. According to Fosch-Villaronga and Millard, "the current legal framework for cloud robotics is characterized by a lack of specific regulation, uncertainties with regard to the application of the existing framework to new technologies, and a lack of clarity regarding basic concepts and definitions."[44]

Some normative and regulatory trends to be considered can be global, such as the high-scale values contained in the Human Declaration of Human Rights[45] and the United Nations Sustainable Development Goals (SDGs);[46] circumscribed to a certain set of states or territories, such as the European Chart of Human Rights,[47] the General Data Protection Regulation[48] and the upcoming Artificial Intelligence Act;[49] or frameworks specifically addressed to AI and technology, such as the Value Sensitive Design (VSD) approach, that is, considering the values not only of the users, but of all others impacted by the outcomes of technology.[50]

### 9.4.3 *Middle-Out/Inside-Out Approach*

There are some notions related to the epistemic approaches to legal and AI governance that can enrich the top-down/bottom-up engineering approach. From a regulatory perspective, *top-down* refers to the decisions taken in upper organization levels and implemented (or enforced) through hard law mechanisms (laws, statutes, acts, and case-based law). *Bottom-up* refers to the negotiated order set by composition, covenants, collective agreements, and dialogical dispute resolution mechanisms. *Middle-out* refers to the mediating layer of technology that pervades any possible solution using information systems and the construction of conceptual and processual toolkits through semantics and AI algorithms (including symbolic AI, neural networks, and machine and deep learning techniques).[51] *Inside-out* refers to the coordination via relevant norms and regulations, stemming from the technical protocols, recommendations, best practices, and standards that are embedded or incapsulated into information and CPS systems, and

43 Fosch-Villaronga, E. and Heldeweg, M., "Regulation, I Presume?" Said the Robot–Towards an Iterative Regulatory Process for Robot Governance. *Computer Law & Security Review* 34(6), 1258–1277, 1259, 2018.

44 Fosch-Villaronga, E. and Millard, C., Cloud Robotics Law and Regulation: Challenges in the Governance of Complex and Dynamic Cyber–physical Ecosystems. *Robotics and Autonomous Systems* 119, 77–91, 83, 2019.

45 www.un.org/en/about-us/universal-declaration-of-human-rights

46 www.undp.org/sustainable-development-goals

47 https://commission.europa.eu/aid-development-cooperation-fundamental-rights/your-rights-eu/eu-charter-fundamental-rights_en

48 https://eur-lex.europa.eu/eli/reg/2016/679/oj

49 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A52021PC0206

50 Friedman, B., Hendry, D. G., and Borning, A., A Survey of Value Sensitive Design Methods. *Foundations and Trends® in Human–Computer Interaction* 11(2), 63–125, 2017.

51 Hence, middle-out refers to forms of regulation such as co-regulation, monitored self-regulation, and coordination mechanisms for AI governance. Cfr. Pagallo, Casanovas, and Madelin (2019).

heading to more abstract principles and regulations, including policies and laws. Normative iterative lifecycles reflect the double looping encompassed by self-organized multiagent systems of smart factories.

It should be noted that these definitions differ from the common understanding of the two terms in computer science, as they are normally used to refer to a functional bidirectional planning or a combined top-down/bottom-up approach.[52] However, from a regulatory perspective inside-out and middle-out should be kept separated, as they point to distinct aspects and steps of the iterative regulatory process. "Inside-out" means that building a specific regulatory model for a computer system should start from the components, subsystems, and systems at stake, as they are designed by the engineers in interaction with the specific needs of the end users, taking into account the different regulations that should be applied at every layer. "Middle-out" refers to the forms of regulation such as co-regulation, monitored self-regulation, and the coordination mechanisms for AI governance (including ethics) that co-occur at each regulatory layer and level of abstraction. This is especially relevant for robots and cobots to interoperate with the environment, as multiagent systems (MAS) can have several degrees of autonomy.

According to the regulatory toolbox set by the *AI4People-on good AI governance* (2019),[53] seven principles could be followed:[54]

(i) *Modular adaptability*, referring to the flexibility of a modular system, that is, the ability to interrelate the separate components of a CPS or parts of a hardware or software package (or also to the partitioning of the design) to make it manageable, so that the system can operate under a wide variety of circumstances.

(ii) *Semantic interoperability*, that is, the ability of computer systems to exchange data with a shared meaning to avoid the ambiguity of natural language. It is a requirement to enable machine computable logic, knowledge discovery, and data federation among different systems; and can be achieved with the use of common ontology or standardized protocol, and more recently, distributed ledger technologies (to exchange digital assets in a secure and decentralized way).

(iii) *Systemic interdependence*, defining the degree of mutual dependency of complex systems, their interrelation, their decomposition into operational sections, and their (global) capacity to generate systemic properties and risks.

(iv) *Organic decentralization*, that is, the processes by which the internal activities of an organization are distributed or delegated away from a central authority, for planning or decision-making purposes; and the way they are linked to its external networks.

[52] That is, "the 'middle-out' systems engineering method consists of concurrent bottom-up and top-down systems engineering activities. The bottom-up tasks are built on a detailed knowledge of component parts and subsystems. The concurrent top-down activities will preserve the customer-focused, requirements-driven emphasis that keeps the system development in a functional domain." Blyler, J., What is middle-out system engineering? DesigNews, December 27, 2019, www.designnews.com/electronics-test/what-middle-out-systems-engineering

[53] Pagallo, U., Aurucci, P., Casanovas, P., Chatila, R., Chazerand, P., Dignum, V., Luetge, C., Madelin, R., Schafer, B., and Valcke, P. "AI4People-on good AI governance: 14 priority actions, a SMART model of governance, and a regulatory toolbox," 2019. www.eismd.eu/wp-content/uploads/2019/11/AI4Peoples-Report-on-Good-AI-Governance_compressed.pdf

[54] Cfr. for a further explanation, Pagallo, Ugo, Casanovas, P., and Madelin, R., The Middle-out Approach: Assessing Models of Legal Governance in Data Protection, Artificial Intelligence, and the Web of Data. *The Theory and Practice of Legislation* 7(1), 1–25, 2019.

(v) *Intermediate conceptualization*, leveraging "legal intermediate concepts" stemming from legal theory – such as property, trust, risk, or guilt – as they are essential to apply and implement the content of legal norms and ethical principles.[55]
(vi) *Coordinated agency*, that is, the capacity of an agent (natural or artificial) to act in a given environment: Software engineering conceives it as a collection of systems made of technical and social (humans and/or organizations) components in which human and artificial behaviors interact.
(vii) *Middle-out (abductive) reasoning*, meaning that the emergence of social effects cannot be inferred from the properties or behavior of a single individual but from the interaction of units or agents; reasoning in a middle-out approach sheds light on the outcomes of a flexible induction vis-à-vis innovation and unintended effects at local level. We are assuming in our approach not just a micro and macro social level, but the emergence of a bridging meso level.

Figure 9.6 plots these principles over the functional mapping of the OPTIMAI Architecture into IIRA, based on the alignment to RAMI 4.0.

### 9.4.4 *Legal Quadrant*

The *enabler* for adding the middle-out/inside-out approach to the whole picture is the dialogic relationship between the vertical enforcement of the *formal* rule of law (based on binding coercive mechanisms) and the horizontal enactment of rights of the *substantive* rule of law (based on individual/collective protections).[56] This entails an empirical perspective. A legitimate normative system always encompasses citizens' participation through social dialogue, negotiation, voting, and the redress mechanisms of democratic political systems. Figure 9.7 draws a legal compass of the rule of law to be used as a starting point for the building of relationships between society, law, and technology.

There are four basic components for the societal implementation of the rule of law and the relationship between them: *hard law*, *soft law*, *policies*, and *ethics*. We looked at the sources, domains, and position with respect to citizens (interconnectedness of norms or rules). Rather than discrete categories or lists of requirements, it is a matter of degree and conditions of values and principles, dealing with the pragmatic dimension of the rule of law.

*Hard law* refers to legally binding obligations, either in the national or international arena, under regulations that can lead to adjudication by court processes. *Soft law*, on the contrary, is not mandatory. It consists of rules, best practices, and principles that are not legally binding, but instead facilitate the governance of networks, social organizations, companies, and institutions,

[55] In legal philosophy, intermediate legal concepts serve as "vehicles of inference" between statements of legal grounds, on the one hand, and legal consequences, on the other. For a formal reconstruction, see Lindahl, Lars, and Jan Odelstad. "Intermediate concepts in normative systems." In *Deontic Logic and Artificial Normative Systems: 8th International Workshop on Deontic Logic in Computer Science, DEON 2006, Utrecht, The Netherlands, July 12–14, 2006. Proceedings 8*, pp. 187–200. Springer Berlin Heidelberg, 2006. Intermediate concepts have been proposed many times in the sciences of design as intermediate design knowledge or generative "strong concepts," Höök, K. and Löwgren, J., Strong Concepts: Intermediate-level Knowledge in Interaction Design Research. *ACM Transactions on Computer-Human Interaction (TOCHI)* 19(3), 1–18, 2012.

[56] In Casanovas, Hashmi, de Koker (2019), we distinguished between *enabling regulatoty systems* (related to stakeholders and referred to the enactment of rights) and *driving regulatory systems* (related to types of norms and referred to their implementation).

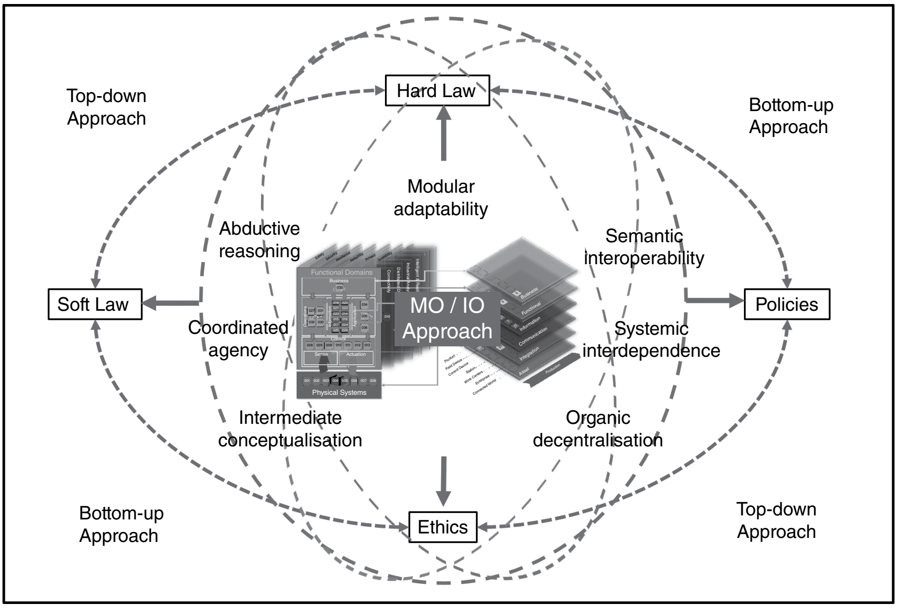


FIGURE 9.6 Middle-out (MO) and Inside-out (IO) multistakeholder legal governance approach over the functional mapping of the OPTIMAI Architecture into IIRA, based on the alignment to RAMI 4.0.

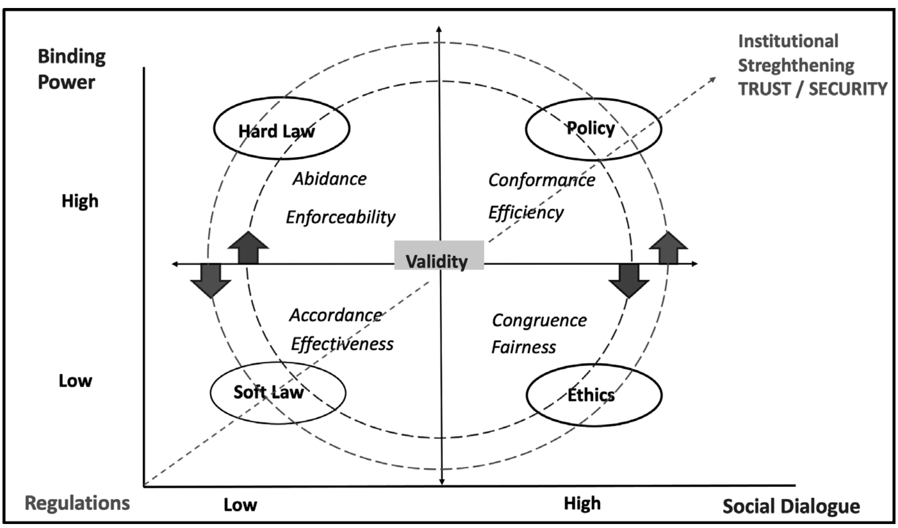


FIGURE 9.7 Legal Compass of the Rule of Law.
Source: Casanovas, Hashmi, and de Koker (2022).

leaving room for dialogue, negotiation, and common accord among relevant actors. Soft law and hard law are not discrete categories but are placed on a *continuum* that allows the coordination of different powers and authorities to produce what can be deemed as *global law* – regulations across borders among citizens, organizations, and the different states. The intuitive approach to first separate binding from nonbinding norms according to the nature of the objectives and procedures has been employed many times.[57]

Figure 9.7 below plots the regulatory quadrant for the rule of law. The validity of norms (i.e., their "legality") emerges from four different types of regulatory frames, with some distinctive properties. Properties are understood here as correlating dynamic patterns. This is a scheme, *a conceptual compass* to be used for the clustering of norms, according to their type and degree of compliance: *abidance* (for hard law), *conformance* (for policies), *accordance* (for soft law), and *congruence* (or congruity) for ethics. According to the degree of abstraction at the implementation level, these four categories can be blurred into overlapping concepts. For example, agreements can be understood as mandatory in the case of corporate policies that may be more binding in practice than some statutes.

The implementation of the rule of law occurs along two different, but related, dimensions at the empirical level: (i) institutional power and (ii) social dialogue (negotiation, compromise, mediation, and agreement). Considering the law, regulations, and power and how it is handled and eventually shared is important. Even at the micro level, this includes a proportional and gradual system of sanctions. There is a wide range of sanctions, from mere incentives to criminal punishment. But we are looking for some value to be assigned to them according to the degree of "bindingness" of norms and the acceptance by stakeholders. As said, the relationship between stakeholders (be they individuals or companies) and the regulatory systems they go by is essential to understand how collective properties can emerge and produce a collective outcome. This line of argument heads to the notion of *Smart Legal Ecosystem*.

## 9.5 SMART LEGAL ECOSYSTEMS

### 9.5.1 *Cloud Robotics Ecosystems and Industrial Robots*

The notion of "ecosystem" has been recently incorporated into the management and business literature. For example, Salenius et al. (2023) propose the notion of "ecosystem shapers" – "processes that shape the early moments of innovation ecosystems at the level of inter-organisational networks" – to understand their development in unsettled industry contexts, particularly "in the spanning of boundaries between legacy stakeholders and new ventures."[58] It is worth noting that institutional and regulatory frames play a role in such analysis.

We have elaborated on Web 2.0 and 3.0, Linked Open Data, and IT business ecosystems elsewhere.[59] A legal ecosystem of artificial/human agents, information processing, robots, and data

[57] Cfr. Brous, Paul, Marijn Janssen, and Riikka Vilminko-Heikkinen. "Coordinating decision-making in data management activities: a systematic review of data governance principles." In *Electronic Government: 15th IFIP WG 8.5 International Conference, EGOV 2016, Guimarães, Portugal, September 5–8, 2016, Proceedings 15*, pp. 115–125; Mondorf, Ansgar, and Maria A. Wimmer. "Requirements for an architecture framework for Pan-European E-government services." In *Electronic Government: 15th IFIP WG 8.5 International Conference, EGOV 2016, Guimarães, Portugal, September 5–8, 2016, Proceedings 15*, pp. 135–150. Springer International Publishing, 2016. For a more extended explanation, cfr. Poblet, M., Casanovas, P., and Rodríguez-Doncel, V. Linked Democracy: Foundations, tools, and applications. Springer Nature, 2019, available at https://link.springer.com/book/10.1007/978-3-030-13363-4

[58] Salenius, V. M., Scataglini, M., Ventresca, M. J., Edmondson, S., Magazzeni, C. M., and Lehmann, D. "Changing Space (S): How Innovation Ecosystems Develop in Unsettled Industry Spaces: a Review and Research Agenda with the Empirical Case of the UK Space Sector Ecosystem." Available at SSRN 4324354 (2023).

[59] Cfr. Poblet, Casanovas and Rodríguez-Doncel (2019), and especially Casanovas, P., de Koker, L., and Hashmi, M., Law, Socio-Legal Governance, the Internet of Things, and Industry 4.0: A Middle-Out/Inside-Out Approach. *Multidisciplinary Scientific Journal* 5(1), 64–91, 2022.

is created and stabilized when the social behavior of autonomous and semiautonomous agents can be embedded, implemented, coordinated, monitored, and controlled within a computer design. Intelligent web services, socio-technical systems, and especially artificial normative socio-cognitive systems share this ability to set social ecosystems, and eventually a community of users. Users interact with each other and with robots within the general frameworks or infrastructures through dataflows that feed and shape the dynamics of the regulatory system. Smart Legal Ecosystems emerge from this interaction.

It is important to distinguish SLE from *Cloud Robotics Ecosystems*. Fosch and Millard define a robot ecosystem as a "complex network of interacting systems comprising the robot, embedded sensors, cloud services, ambient intelligent systems, and any device or sensor supporting robot task performance."[60] As previously shown on the description of OPTIMAI architecture and dataflows, CPS may contain several ecosystems of this kind. Again, it is useful to keep separated the macro, meso, and micro levels in which human–machine interactions occur. It depends on the level of abstraction we are considering when describing information processing.

We should also differentiate it from *Industrial Robots Ecosystems* as well.[61] According to the Robotics Industrial Association (RIA) definition, *a robot is a reprogrammable multifunctional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks, which also acquire information from the environment and move intelligently in response*. The IoT and data-driven technologies used in I4.0 add complexity to this definition. I like the following simple definition, as it shows the evolution: "*intelligent connection* between perception and action."[62]

However, nothing ensures that these ecosystems are also *legal*, that is, compliant with all legal instruments that may apply to them and according to which they have been built from the inside (including policies, soft law, and ethics, as shown in Figure 9.7). These are components of legal governance that can be combined in several ways and degrees to generate the validity (or legality) of the regulatory system. Legal governance can be defined as an explanatory and validation concept to support the implementation of the rule of law in I4.0 and I5.0 environments. It can be understood as a process in which rights can be enacted and norms implemented (mainly through rules). A legal (or socio-legal) ecosystem emerges from the interaction between all stakeholders, building, first, and then using the system.

### 9.5.2 *Compliance* by *Design (CbD) and Compliance* through *Design (CtD)*

The convergence between Web 4.0, I4.0, and the IoT has already challenged the regulatory landscape (relating to law, governance, and the legal professions) and raise new regulatory challenges regarding, for example, legal liability, data rights, data protection, trade restrictions, agreements, standards, contract models, supervision, security, monitoring, and control.[63] Some years ago, Leenes and Lucivero (2014) distinguished the following categories: (i) Regulating robot design production *through law*; (ii) regulating user behavior *through the robot's design*; (iii) regulating the effects of *robot behavior through law*; and (iv) regulating *robot behavior*

[60] Fosch and Millard (2019), p. 87.
[61] Sanneman, L., Fourie, C., and Shah, J. A., The State of Industrial Robotics: Emerging Technologies, Challenges, and Key Research Directions. *Foundations and Trends® in Robotics* 8(3), 225–306, 2021.
[62] De Luca, Alessandro. *Industrial Robotics*. PP. La Sapienza, Rome, Italy, 2021.
[63] Cfr. Pagallo, Casanovas, Medelin (2019), and Casanovas, Hashmi, and de Koker (2022).

*through code*.[64] Leenes et al. identified a "robot" positioning it into five dimensions: (i) *nature* (which refers to the material in which the robot manifests itself); (ii) *autonomy*, which refers to the level of independence from external human control; (iii) *task* (which refers to the application or the service provided by the robot); (iv) *operating environment* (which refers to the contexts of use); and (v) *human–robot interaction* (which refers to the relationship established with human beings).[65]

The example of OPTIMAI shows that in last data-driven platforms generation these dimensions can be combined in different ways to stabilize regulatory effects through information-processing chains. We use the term *Compliance through Design* (CtD) to refer to HRI patterns of behavior (i.e., both human and artificial) that emerge from turning *ethical* and *legal* requirements into *social* conditions that can be followed and accepted by end users and stakeholders participating into the SLE. Human–robot interaction occurs in micro situations that can be shaped and partially designed in advance to create HRI patterns.

CtD, that is, *legal* CtD should be differentiated from *regulatory* Compliance by Design (CbD). CbD occurs in business and corporate environments through specific business compliance languages for conformity check, in or after the runtime stage or in the design stage of business processes. As defined by Hashmi et al. (2018), "regulatory compliance aims to ensure that organisation's business operations are in alignment with the governing laws of the organisation or the laws from regulatory bodies."[66] CbD refers broadly to the set of formalized rules that are considered in the design stage of a business or regulatory process. CtD is broader in scope, encompassing all the elements of legal governance, and focusing on enabling and driving the regulatory system to become a running legal ecosystem in the hybrid space of HRI, that is, from a legal implementation perspective.[67] It incorporates the middle-out/inside-out approach previously described, and it explicitly encloses the social and institutional aspects of legal compliance (i.e., legal interpretation processes, institutionalization, the interface between modelling and coordination, and the relation between the regulated entity, the law, and citizens (with different roles: consumers, managers, workers, etc.). Hence, CtD bears upon the legal ecosystem, and can be institutionalized but not fully automated, as it typically combines coding, information processing, experience, formal and informal behavior, and human decision-making.

Figure 9.8 exemplifies HRI planning through technical and normative requirements. This is one of the OPTIMAI pilots on defect detection in a Hydraulic lift Power Unit Quality Control. Currently, in case that the testing measurements indicate a defect, only the experienced operators know what might do to resolve the issue. Any cause of suboptimal performance and the corresponding corrective actions should be notified to the users (production managers). This process can be partially automated through digital twins' technology.[68] Users should be able to test different set up parameters in the production line and to transfer the optimal ones set up by the virtual testing to the real production line.

[64] Leenes, R. and Lucivero, F., Laws on Robots, Laws by Robots, Laws in Robots: Regulating Robot Behaviour by Design. *Law, Innovation and Technology* 6(2), 193–220, 198, 2014.

[65] Leenes, R., Palmerini, E., Koops, B.-J., Bertolini, A., Salvini, P., and Lucivero, F., Regulatory Challenges of Robotics: Some Guidelines for Addressing Legal and Ethical Issues. *Law, Innovation and Technology* 9(1), 1–44, 4, 2017.

[66] Cfr. Hashmi, M., Governatori, G., Lam, H.-P., and Wynn, M. T., Are We Done with Business Process Compliance: State of the Art and Challenges Ahead. *Knowledge and Information Systems* 57(1), 79–133, 2018.

[67] Hashmi, M., Casanovas, P., and de Koker, L. Legal compliance through design: preliminary results of a literature survey. *TERECOM2018@ JURIX, Technologies for Regulatory Compliance* http://ceur-ws.org 2309 (2018): 06.

[68] Mastos, Theofilos et al. (2021).

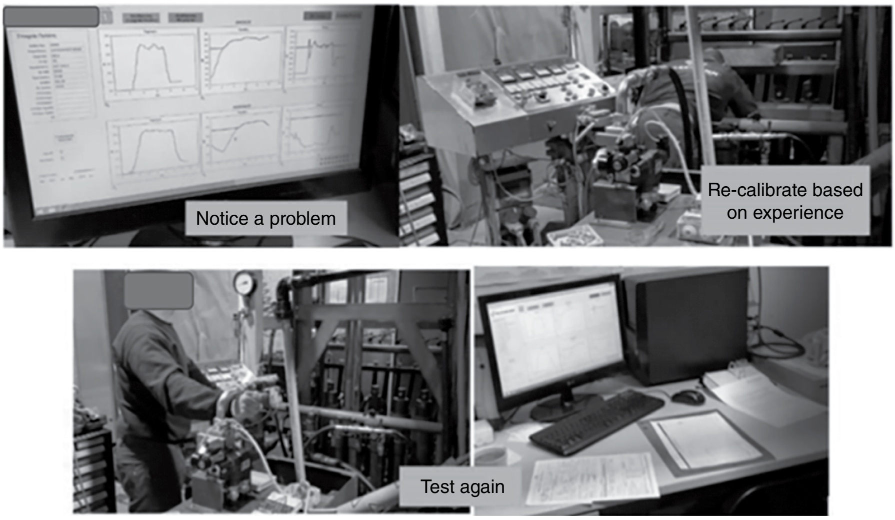


FIGURE 9.8 Current procedure to be automated in a Hydraulic lift Power Unit Quality Control. Source: Mastos et al. (2021, 29).

### 9.5.3 *From Socio-Legal Ecosystems (LE) to Smart Legal Ecosystems (SLE)*

Legal ecosystems are socio-legal ecosystems, meaning "all processes, interactions and exchange of information involved in the social and cultural implementation of a regulatory system, including its design, monitoring, and users' compliance and behaviour."[69] But beyond its social nature, its design must also encompass, select, and implement as constraints the content of several normative bodies coming from different jurisdictions (regional, national, international), that is, from legitimated legal sources. Fundamental questions and principles related to obligations/responsibilities, and liability/rights/accountability hold on the IoT.[70] IoT ecosystems on the web of data involve privacy, consumer, and data protection, and different types of contracts, licenses, insurances, and patents (Santos et al. 2016).[71]

Thus, a legal ecosystem can be defined as a complex and dynamic system that includes multiple levels of governance, ranging from local to national and international, and involves a wide range of actors, including lawmakers, judges, lawyers, law enforcement officials, civil society organizations, and ordinary citizens. However, the specific components and interactions within a legal ecosystem can vary significantly depending on factors such as the legal tradition, political system, cultural context, and economic conditions of the jurisdiction in question.

Hence, following the example of Figure 9.8, many other requirements apply. Some of them can be embedded into the system to improve operator–machine interactions. Others must be specified separately to shape the whole HRI. For instance, (i) *integrity* (related to the physical and mental integrity of human beings); (ii) *equality and nondiscrimination* (related to all

[69] Poblet, Casanovas, and Rodríguez-Doncel (2019), pp. 108–109.
[70] Millard, Christopher, W. Kuan Hon, and Jatinder Singh. "Internet of Things ecosystems: unpacking legal relationships and liabilities." In *2017 IEEE International Conference on Cloud Engineering (IC2E)*, pp. 286–291. IEEE, 2017.
[71] Rodriguez-Doncel, V., Santos, C., Casanovas, P., and Gómez-Pérez, A., Legal Aspects of Linked Data–The European Framework. *Computer Law & Security Review* 32(6), 799–813, 2016.

persons at work); (iii) *protection of personal data* (related to persons' identity, "data subjects"); and (iv) *health, safety, and dignity* (related to persons' well-being). Some requirements refer to the workers' condition, for example, offering opportunities to persons with disability (according to the degree and kind of disability they suffer). Other requirements refer to AI use, for example, the system should be designed and developed in such a way that enables human oversight. Thereby, including appropriate human–machine interface tools to test the accuracy, robustness, and security of the system.

Ethical and legal requirements have been clustered in OPTIMAI under the topics of (i) Data Protection; (ii) Security, Health and Safety; (iii) Equality, Fairness and Non-Discrimination; (iv) Human Agency and Oversight, Accountability, Transparency and Accuracy; and (v) Meaningful Work and Impact on Work and Skills.[72] An SLE should be able to encompass them to foster a safe environment. For example, according to most labor national legislations, feedback from users and operators regarding how the tool impact their work, especially from the perspective of agency and autonomy, should be collected. Their perceptions and opinions matter to create SLE. Feedback should be directly collected from operators who might be affected by wearables and AR. Have these tools changed the self-perceived nature of their behavior in the workplace? Do these changes have a positive impact? Are the Manufacturing Ecosystem and the CRE compliant with the regulatory models that have been built to implement SLE?

We should distinguish emerging behavioral patterns and routines from the enactment of the regulatory and legal conditions that can make them happen. Smart Legal Ecosystems reunite both sides, constitutive and regulatory, to create data-driven and rights-enabled cycles with human participation.[73]

### 9.5.4 *Users' Experience and Intelligent Environments*

Smart Legal Ecosystem should also be distinguished from (but it is related to) Human-centered Design (HCD) and Intelligent Environments (IE) models and frameworks. In HCI, end users' activities and roles have been enriched with the notion of user's *experience* (UX). User's experience subsumes "usability," incorporating the cognitive and dynamic aspects that humans build in HRI to understand and manage affordances and to situate themselves into digital environments, including emotional behavior. Intelligent Environments constitutes a new field of research in HCI focusing on supporting and empowering users, increasing, and improving their experience and skills from a holistic perspective.

Human-centered Design was incorporated by ISO 13407:1999 into the design standards (Human-Centered Design Processes for Interactive Systems). As explained in detail by Margetis, Ntoa, and Antona (2021), ISO 13407 was replaced by ISO 9241-210: 2010, which has

[72] Teodoro, Emma, Andrea Guillén. Coauthors: Agata Gurzawska, Paul Hayes, Pompeu Casanovas. D9.1: *Report on the OPTIMAI Ethical and Legal Framework.* Optimizing Manufacturing Processes through Artificial Intelligence and Virtualization, OPTIMAI, EU H2020 Project, 30 June (2021).

[73] Compare Casanovas, Pompeu; Emma Teodoro, Andrea Guillén, Mustafa Hashmi, Coauthors: Agata Gurzawska, Paul Hayes. D9.5: *Report on the OPTIMAI Regulatory Model – 1st version*. Optimizing Manufacturing Processes through Artificial Intelligence and Virtualization, OPTIMAI, EU H2020 Project, 1 January (2021); Casanovas, Pompeu; Mustafa Hashmi, Emma Teodoro, Andrea Guillén, Coauthors: Agata Gurzawska, Paul Hayes. D9.6: *Report on the OPTIMAI Regulatory Model – 2nd version*. Optimizing Manufacturing Processes through Artificial Intelligence and Virtualization, OPTIMAI, EU H2020 Project, 30 June (2021).

been also recently revised with minor updates by ISO 9241-2010: 2019. The main changes introduced were to clarify the role of iteration in the entire design process and emphasize that HCD methods can be used throughout the system lifecycle. The current ISO foresees the following principles: (i) The design is based upon an explicit understanding of users, tasks, and environments, (ii) users are involved throughout the design and development, (iii) the design is driven and refined by user-centered evaluation, (iv) the process is iterative, (v) the design addresses the whole user experience, and (vi) design is performed by multidisciplinary teams and from multidisciplinary perspectives.[74] These are reflected in four iterative activities that, to mention the authors' metaphor, are "travelling to unknown destinations": (i) understand and specify the context of use, (ii) specify the users' requirements, (iii) produce design solutions, and (iv) evaluate the design. They individuate and analyze six HCD fundamental concepts: explainable AI and human-in-the-loop, semantic cognitive and perceptual computing, visual predictive analytics, interactive machine learning, federated learning, and UX design for AI.

Following Ntoa et al. (2021), OPTIMAI follows these design principles, bringing into its framework a set of methodologies based on the concept of IE, as "intelligent environments impose novel challenges to the evaluation of UX. Such challenges pertain to the nature of interaction, which shifts from explicit to implicit, encompasses novel interaction methods, and is escalated from one-to-one to many-to-many interactions. At the same time, intelligent environments besides human–thing interactions also encompass 'thing-to-thing' interactions, which introduce additional concerns regarding conflicts' resolution, interoperability, and consistency of interactions."[75] Intelligent Environments have several attributes, identified as interconnected, pervasive, transparent and nonintrusive, able to recognize objects and people, learn from their behavior, and adapt to support them. The UXIE framework foresees the evaluation of seven fundamental attributes: intuitiveness, unobtrusiveness, adaptability and adaptivity, usability, appeal and emotions, safety and privacy, as well as technology acceptance and adoption.[76]

How SLE can be made compatible with IE modelling, metrics, and evaluation methods? How SLE can be aligned with IE regulatory tools and power? This is an open challenge, but the answer might lie in the pragmatic normative dimension of SLE. For UXIE purposes, "privacy" and "safety" are parameters of the overall user experience and acceptance of the technology at stake, that is, *attributes*, components, of the proposed framework; and "conformance with guidelines" is a subcomponent, among others, of the attribute "usability." Thus, *legality*, or the legal value of the overall system known as "validity," is not specifically defined and individuated.

The attributes of SLE – to be defined around the main properties of "abidance," "conformance," "accordance," and "congruence" of norms on the four clusters of the legal compass

[74] Margetis, G., Ntoa, S., Antona, M., and Stephanidis, C., Human-centered Design of Artificial Intelligence. In G. Salvendy and W. Karwowski (eds.), *Handbook of Human Factors and Ergonomics*. John Wiley & Sons, Inc., 1085–1106, 2021. The authors draw a complete framework for systematically pursuing human-centered design for AI.

[75] Ntoa, S., Margetis, G., Antona, M., and Stephanidis, C., User Experience Evaluation in Intelligent Environments: A Comprehensive Framework. *Technologies* 9(2), 41, 2021. The authors introduce a User Experience in Intelligent Environments (UXIE) methodological framework, developing an "iterative design approach, suggesting specific evaluation approaches for the different development stages of an intelligent environment, system, or application, thus allowing the assessment of the user experience from the early stages of the development lifecycle to the final stages of implementation." They also propose 103 concrete metrics and several methods to measure them.

[76] Ntoa et al. (2021), ibid.

(Figure 9.7) – could be better situated as *orthogonal* with respect to the IE modelling, metrics, and evaluation. Likewise, SLE entails a holistic, hybrid (H/M), semiautomated, and indirect behavioral approach, so that "human expertise cannot be substituted by any automated evaluation or simulation tool." Law (and ethics) shares with sustainable effects and pattern modelling their specific and contextual scope. However, literally, any component and element of an interactive transaction can be evaluated from a legal point of view as a distinct dimension, encompassing norms and degrees of implementation at every layer with the (partial or full) enactment of rights. An empirical methodology can take into account these features to elaborate a set of separate metrics for legal compliance.[77]

## 9.6 CONCLUSIONS AND FUTURE WORK

Human–robot interaction cannot be taken for granted. Actual performances and routinization of processes depend on too many variables to offer a standardized model that can be used as a template. As full and achieved processes, Smart Industry and Manufacturing Ecosystems are under development. They do not yet exist as such, and much more sandboxes and feasible projects end experiences would be needed to generalize and standardize them. Likewise, SLE are in a development phase.

This chapter has shown that the inception of data-driven platforms for smart manufacturing is a first step. What it has been contended is that the effective regulation of HRI is becoming part of the same process. Its legal fragmentation cannot be solved only with the use of traditional legal instruments (such as hard and case-based law), but through the assembling and coordination of legal governance tools, with the participation of all stakeholders. This toolkit is also being created in the same path as smart manufacturing evolves in data-driven and AI applications ecosystems.

One of its crucial components is legal compliance and the languages and metrics to implement it.[78] Compliance has been the subject matter of corporate and business models for more than a decade now. There are several business and policy languages. However, smart validation processes on the layered architectures of IoT environments must still be deployed. It is a hot topic for the immediate future, as the whole information lifecycle should be designed and monitored to foster trust, transparency, and accountability in a sequential, controlled process deemed as "valid" or "legal" *by* or, better, *through* design. Trust is not necessarily a direct product of compliance, but it is a by-product of the conditions created by dynamic and sustainable legal ecosystems, that is, through SLE.

*Compliance through Design* (CtD) can be decomposed from different approaches to select several implementation types according to the normative environment, the selection of formal languages, stakeholders, and the kind of processes to be regulated. As Lam and Hashmi assert, legal compliance can be graduated and divided into regulatory compliance, legal compliance, partial compliance, full compliance, distributed compliance, and so on.[79] Explaining how

[77] Compare the legal scheme, metamodel and causal model for legal governance proposed in Casanovas, Pompeu, Mustafa Hashmi, and Louis de Koker. "A Three Steps Methodological Approach for Legal Governance Validation." *AICOL@ JURIX* (2021).

[78] Casanovas, Pompeu; Mustafa Hashmi, Emma Teodoro, Andrea Guillén, Coauthors: Agata Gurzawska, Paul Hayes. D9.7: *Report on the OPTIMAI Regulatory Model* – 3rd version. Optimizing Manufacturing Processes through Artificial Intelligence and Virtualization, OPTIMAI, EU H2020 Project, 31 December (2021).

[79] Lam, Ho-Pun, Mustafa Hashmi, and Akhil Kumar. "Towards a Formal Framework for Partial Compliance of Business Processes." In *AI Approaches to the Complexity of Legal Systems XI-XII: AICOL International Workshops 2018 and 2020: AICOL-XI@ JURIX 2018, AICOL-XII@ JURIX 2020, XAILA@ JURIX 2020, Revised Selected Papers*, pp. 90–105. Cham: Springer International Publishing, 2021.

compliance can be embedded into legal ecosystems – with both human and artificial agents – comes next in I5.0.

Other important challenges related to SLE and CtD include the building of *legal knowledge graphs* (in which heterogeneous data sources from different jurisdictions, languages, and orders are aggregated and interlinked by a collection of advanced services),[80] *ethically aligned reasoning* – that is, "designing processes to explicitly capture the values of stakeholders so that they can be appropriately considered both throughout any design and deployment process,"[81] and what we can call *anchoring institutions* – that is, the hybrid regulatory frameworks to "anchor" regulatory LSE into specific social fields, communities, and organizations. As already said, all these trends come next in I5.0 developments, to be aligned *orthogonally* with the already existing models and metamodels for the evaluation of HRI, users' experience, and the scenarios set up within IE.

[80] Compare the results of the H2020 EU Project LYNX, *Building the Legal Knowledge Graph for Smart Compliance Services in Multilingual Europe*, https://cordis.europa.eu/project/id/780602

[81] Noriega, Pablo, Harko Verhagen, Julian Padget, and Mark d'Inverno. "Design heuristics for ethical online institutions." In *Coordination, Organizations, Institutions, Norms, and Ethics for Governance of Multi-Agent Systems XV: International Workshop, COINE 2022, Virtual Event, May 9, 2022, Revised Selected Papers*, pp. 213–230. Cham: Springer International Publishing, 2022.