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Social Dimensions in CPS & IoT Based Automated Production Systems

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Abstract: Since the 1970s, the application of microprocessor in industrial machinery and the development of computer systems have transformed the manufacturing landscape. The rapid integration and automation of production systems have outpaced the development of suitable human design criteria, creating a deepening gap between humans and systems in which human was seen as an important source of errors and disruptions. Today, the situation seems different: the scientific and public debate about the concept of Industry 4.0 has raised awareness about the central role humans have to play in manufacturing systems, the design of which must be considered from the very beginning. The future of industrial systems, as represented by Industry 4.0, will rely on the convergence of several research fields such as Intelligent Manufacturing Systems (IMS), Cyber-Physical Systems (CPS), Internet of Things (IoT), but also socio-technical fields such as social approaches within technical systems. This article deals with different human social dimensions associated with CPS and IoT and focuses on their conceptual evolution regarding automated production systems' sociability, notably by bringing humans back in the loop. Hereby, this paper aims to take stock of current research trends to show the importance of integrating human operators as a part of a socio-technical system based autonomous and intelligent products or resources. Consequently, different models of sociability as a way to integrate humans in the broad sense and/or the develop future automated production systems have been identified from the literature and analysed.

Keywords: industry 4.0; cyber-physical systems (CPS); internet of things (IoT); human factors; automated production systems; social interactions; social networks

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1. Introduction—Ground-Breaking Changes in Industry Worldwide

Today, the German initiative "Industrie 4.0" (https://www.plattform-i40.de/PI40/Navigation/EN/Industrie40/WhatIsIndustrie40/what-is-industrie40.html (accessed on 14 June 2021)) [1], along with many other national socio-political programs such as "Industrie du future" in France (https://www.economie.gouv.fr/lancement-seconde-phase-nouvelle-france-industrielle (accessed on 14 June 2021)), "High Value Manufacturing Catapult" (HVMC) in the United Kingdom (https://hvm.catapult.org.uk/ (accessed on 14 June 2021)), "Made in China 2020" (http://english.www.gov.cn/2016special/madeinchina2025/ (accessed on 14 June 2021)), "Manufacturing USA" (https://www.manufacturing.gov/programs/manufacturing-usa (accessed on 14 June 2021)), etc. are fostering the digitisation of industry and are taken as references for the development of new manufacturing systems. The strong stakes associated with their simultaneous and worldwide emergence make them the foundations of the 4th industrial revolution as it is already considered by experts.

Basically, the technical innovations related to the vision of Industry 4.0 implies the wide-spread adoption of Cyber-Physical Systems (CPS), the integration of products, smart factories, and the introduction of value chains into global business networks [2–6]. Such technical integration also correlates with a vision of increased control of highly complex and globalised production processes, also motivated by the expectation for a (partial) reshoring of production capacities. Other frequently discussed technologies in the context of Industry 4.0 are adaptive robotics, additive manufacturing and job-related wearables that are slated to contribute to productivity increases [7]. All these technologies are grounded on paradigms such as CPS or Internet of Things (IoT), where the continuous automation of processes plays a huge role [2].

New objectives will be to achieve the networking of humans, objects, and their virtual representations within complex-adaptable socio-technic industrial systems. IoT and CPS are positioned as two essential representations into the study and development of future industrial systems, but equally for the development of the digital society in general. In this context, one of the most advanced examples is the Japanese initiative Society 5.0, presented in 2016 at the Japanese 5th Science and Technology Basic Plan, at the German Center for Office Automation, Information Technology and Telecommunications (CeBIT), and described by Fukuyama [8]. In this vision, technical innovations of the 4th industrial revolution are integrated into every aspect of industrial and social landscapes, as a new 5th wave characterized by the information society. However, the described system can be considered as utopian by the complexity and uncertainties attached to its concretization [9]. One of these uncertainties lies in the two kinds of relationships underlying this Society 5.0 identified by Deguchi et al., that are “the relationship between technology and society and the technology-mediated relationship between individuals and society” [10].

This debate on the links between society and technology is naturally found in socio-technical systems, such as production ones [2,3,7,11–16]. The place of humans and his consideration into the design of the latter have also become a very important issue, giving rise to several systems engineering visions and approaches. In this context, the generic Human Systems Integration (HSI) concept is both used in research fields interested in human factors and in systems engineering, aiming to associate notions of human performance and technology design [17] to systems’ design. In addition, HSI concept echoes the user-centric system (or Human-centred or Anthropocentric) design approach, that can be found under the standard ISO 9241-210:2019, as “A way of designing interactive systems, aiming to make systems usable and useful by focusing on users, their needs and requirements, and applying human factors, ergonomics and existing knowledge and techniques in terms of usability” [18].

From another viewpoint, Human Centered Design is presented by G. Boy as an interdisciplinary and systemic approach toward HSI mixing “cognitive engineering, advanced human-computer interaction (HCI), modeling and simulation, complexity management, life-critical systems, and organization design and management.” [19]. More recently, the “Inclusion” concept, grounded on educative sciences and consisting in adapting a given process by considering individual characteristics instead of collective or standard goals, was extended to human manufacturing system inclusion [20,21].

This development echoes David Lockwood’s sociological theory of social systems, defined as social integration. In his works, social inclusion/integration differs from common system integration by considering mutual relationships among individual actors and groups in a system, to achieve “conscious and motivated interaction and cooperation”, instead of anonymous coordination mechanism [22]. Therefore, the emergence of CPS as a new wave of automated production system, motivates to privilege this social integration concept [23,24]. Notably, the development and use of social interaction between objects and humans could today be envisioned as a key enabler of the extension of the paradigms of CPS and IoT to human beings in industry.

The first contribution of this article is to provide an overview of human social dimensions’ place in CPS and IoT in literature, detailing their specificities, contributions, and potential regarding automated production systems in the broader context of Industry 4.0.

The second contribution figures out, where automation processes are going on and how humans are integrated within these systems. Because the ongoing process of automation belongs to the inner logic of industry, this aspect becomes explicit in the following paper, which is structured as follows. Section 2 will detail some fundamentals concerning CPS and IoT paradigms, and the role to be given to them within these automated production systems. Section 3 will discuss different models of sociability defined as the ability to interact with others, including human-machine, machine-machine, human-human interactions, to illustrate the purpose of Section 2. Due to these complex developments, the hypothesis that the engineers and developers intend automation on different process levels is implicitly raised. Section 4 will conclude by raising open questions concerning work automatization and questioning how automation is changing work quality today.

2. Fundamentals on CPS and IoT—An Insight

The notions of CPS and IoT are generally recognized as the main pillar of Industry 4.0 [4,7] Decades ago, the debate on Computer Integrated Manufacturing (CIM) systems referred intensively to new technological and social dimensions with a huge societal impact [23]. However, recent associated technical integration systems encompass this debate with a different focus [24–28]. Technological dimensions are related to the connection between the technical systems, while sociological dimension is related to communication and interfacing human and technical systems. In both cases, integration has to consider the following:

(a) machine-machine interaction,
(b) human-machine interaction and
(c) human-human interaction.

The introduction of CIM systems in the 1980s had fundamental effects on the organizational level of work. On the one side, digitization of work processes created a vision about the complete automation of factories without personnel [23]. Yet, on the other side, the high level of technical standards created a discourse about the rising and dependent scope of human actions within working processes [2].

We call "restrictive" a work organization based on a strict human-machine interaction in a delimited workspace, dependent on technical parameters and on rational production lines. This organization disappears while considering the support of qualified and responsible employees, which should be actively involved in the production processes. It must be noted that such flexible work organization is more complex to design than ones restricted to the mechanistic and hierarchical principles of management. The participation of the employees into these processes should imply the introduction of tacit knowledge, planning and operation, group work, as well as decision-making processes.

These criteria are, again, at stake when the emergent vision of the new automated production systems designed with CPS and IoT are debated [5–7,13,29–31]. Observations have already shown that these distributed internet-based systems bring path dependencies that may restrict the possibilities for alternative work organization models by automation [32–34]. If human factors are not included simultaneously with technological factors in the design process, there is little space for "re-automation" regarding human interference into the work processes [25].

Due to the wide range of its potential applications, this concept of CPS enjoys great popularity in the scientific world, although it is rather recent (enunciated by Lee in 2006) [35]. However, popularity and novelty make it a concept whose definition and scope are rather blurred. It is also often associated with the one of IoT, which appeared a little earlier in the 2000s [36,37].

According to Bril El-Haouzi [25] and Bordel et al. [38], preferences in the use of the terms CPS and IoT are observed from one scientific community to another, or from one geographical area to another. Thus, CPS will be preferred to IoT in mechatronics and IoT in computer science communities. The term CPS are also found more often on the American continent than in Europe or Asia, where IoT is preferred [25,38]. Yet, these two concepts are fundamentally different and need to be differentiated.

The popularity of the IoT concept has been presented in literature with many definitions. Notably, Madakam and colleagues conducted a literature review in 2015, which led them to formulate the following definition: "an open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data, resources, reacting and acting in face of situations and changes in the environment" [39]. Concerning CPS, Lee initially enunciated the concept as being "integration of computation with physical processes" where "embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa" [35]. It can be noted that this definition stays consistent with the one fostered more recently by Monostori "systems of collaborating computational entities which are in intensive connection with the surrounding physical world and its on-going processes" [40].

These first definitions can be characterized as techno-centred since only technical aspects of CPS and IoT are exposed, while human is not evoked. Hence a system can be considered as being composed of both objects and their cyber representations. In other words, a system can be seen as organized along two axes: the first one representing the physical world; the second one representing the cyber world. On the one hand, IoT would correspond to the horizontal connectivity and synchronization between physical or cyber objects, performed thanks to internet data exchange protocols-based technologies (such as TCP/IP). On the other hand, CPS would correspond to the vertical connectivity and synchronization between objects and their cyber representation, performed thanks to cloud and sensors-based technologies [6,11,32,41,42] (Figure 1).

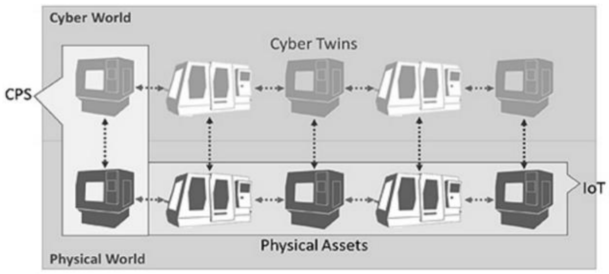

Figure 1. CPS & IoT (see [11]).

Therefore, CPS and IoT can be seen as the two main enabling paradigms for Cyber-Physical systems' networking, and two of the main pillars for Industry 4.0. This representation seems well-suited to describe machine-machine interaction. But as expresses here above, human-human interaction and human-machine interaction (e.g., HSI) are equally important regarding Industry 4.0 [2,25].

Nonetheless, these aspects have been tackled for both IoT and CPS in the last decade. Figure 1 shows the results for the searches (S1): "Cyber Physical Systems" AND (Human OR Social OR Anthropocentric) and (S2): "Internet of Things" AND (Human OR Social OR Anthropocentric). This search was performed with the ScienceDirect scientific database for practicality of use. No other database was queried, for the purpose of this search is to provide an overview of the scientific interest for the subject and not an exhaustive analysis. To obtain relevant results, the search has been restricted to articles (research and reviews), presenting the terms in their title, abstract or keywords. Hence, searches target the articles instead of only mentioning them, but for which they are the main subject (Figure 2).

Overall, the interest shown for this research area has risen consistently for the last decade. The decrease observed for 2020/2021 was due to an update delay in the database (for instance, results for CPS in 2020 have risen from 45 to 50 between April and May 2021). In a prior paper, Valette et al. have already proposed a study upon the human-integration the evolution of CPS and IoT paradigms regarding human, anthropocentric and social characters [32].

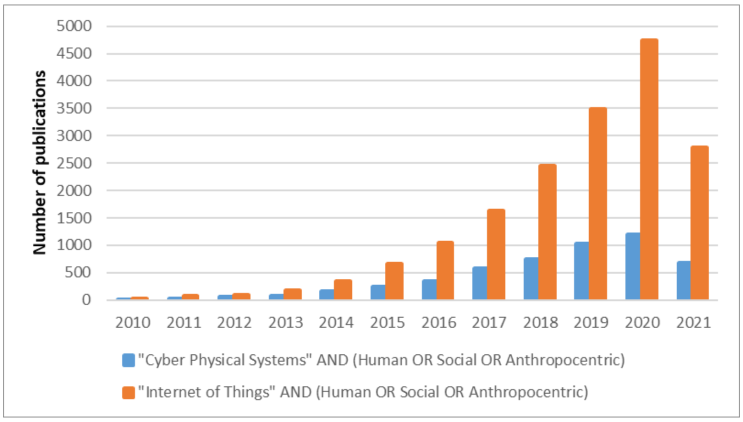

Figure 2. Results for the searches (S1) and (S2) in ScienceDirect scientific Database (April 2021).

What will be deepened in this paper is the social character, often associated with the development of systems and of their architectures. As Moniz and Krings mentioned, the application of new robotic systems in the manufacturing shop-floor level is widely undertaken without the reference of «real» social implications. Due to the cognitive and perceptual workload for new robot operators in complex and automated working systems, the social dimension is currently defined by developers with the focus on the issues of security and, eventually, qualification. However, the social dimension remains in a limbo regarding the technical debate about interaction systems [26].

The analysis concerning the impact of automation on work processes is closely connected with the knowledge about social issues at work level. If the term "social" can be seen as the most generic to express human consideration for production systems design in literature, it is, however, not unambiguous nor necessarily the mark of an attention paid to the human being. We can especially cite its use in a multi-agent field, where any interaction between two agents, human or not, is called social.

Notably, the 1998 work from Sycara can be quoted, where "sociability" is referring to the fact "that an agent is capable of interacting in a peer-to-peer manner with other agents or humans." [33], along with more recent works from Nguyen and Katarzyniak, establishing as social interactions "all acts, actions and practices that involve more than two agents and affect or take account of other agents' activities, experiences or knowledge states" [43]. Hence, social integration models/approaches can be divided into the three types: social interactions based on peer-to-peer communication interfaces, social-network services based approach as a media for social interaction and human-inspired social relationships-based a sociability model, detailed in the following sections.

3. Social Aspects in IoT and CPS

3.1. Social Interactions Based on Peer-to-Peer Communication Interfaces

The "classic" approach, mostly found in the Multi-Agent Systems (MAS) study field, defines as social any agent able to interact with another one, whether it is artefactual or natural. The developments we would classify here aim mainly at human physical enhancement through technological means, with the purpose of human integration in such systems. Hence, Sowe et al. define a Cyber-Physical Human System as an "interconnected systems (computers, cyber physical devices, and people) "talking" to each other across space and time, and allowing other systems, devices, and data streams to connect and disconnect" [44]. This definition is found in the work of (Schirner et al. 2013), who developed the 'Human-in-The-Loop Cyber-Physical Systems' (HiTLCPS).

This concept consists of an embedded system improving the ability of a human being to interact with his physical environment (Figure 3). The "loop" is made up of a human, an embedded system, and their environment. Beyond the very concrete translation of the integration of the human factor into systems, they provide here a solution where the system is presented as a physical extension of the human being, via a digital interface.

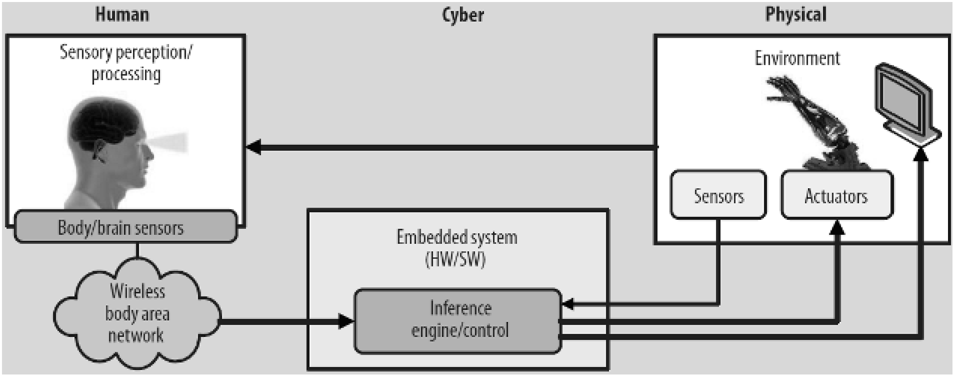

Figure 3. HiTLCPS (see [34]).

With the development of the 'Anthropocentric Cyber-Physical Systems' (ACPS) by Pirvu and colleagues [27], defined as a reference architecture integrating the three physical, cyber/IT and human components (Figure 4), the search for the integration of the human factor is taken further. The authors present it as an integrated, social, local, irreversible, adaptive, and autonomous system, in line with the continuity of Cyber-Physical Social Systems (SCPS) and Cyber-Physical Social Systems (CPSS). The ACPS is presented as an architecture "where the humans are not just interactants with a CPS, but elements of the system affecting its lifetime behaviour" [27]. However, unlike previous contributions offering concrete applications, this one pushes human integration further but remains, therefore, very conceptual.

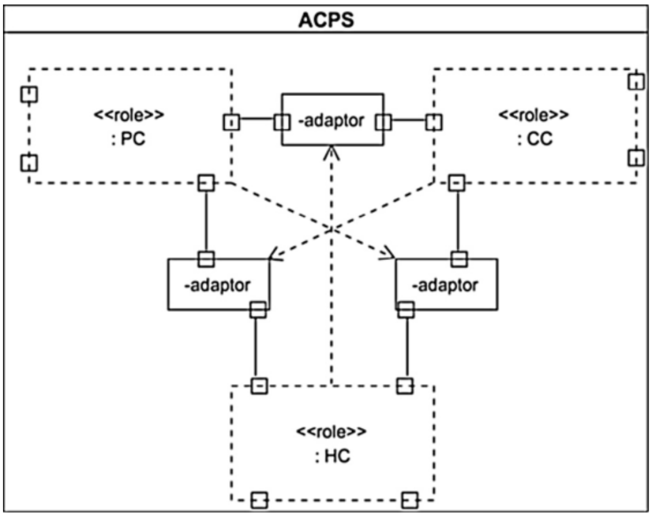

Figure 4. ACPS reference architecture (see [27]).

Until now, the most recent development of these approaches is the 'Social Human-In-The-Loop Cyber-Physical Production System' (Social-HITL-CPPS) of [45]. In this paper, the interpretation of a human agent's behaviour and its coordination with other agents are identified as the two main challenges of the integration of humans in social (and not just industrial) environments.

To meet these challenges, a three-layer architecture has been proposed. This architecture connects, on the one hand, human users to the cyber part via user interfaces, and on the other hand, the physical parts (i.e., non-human agents and the environment) to the cyber part via a network (Figure 5).

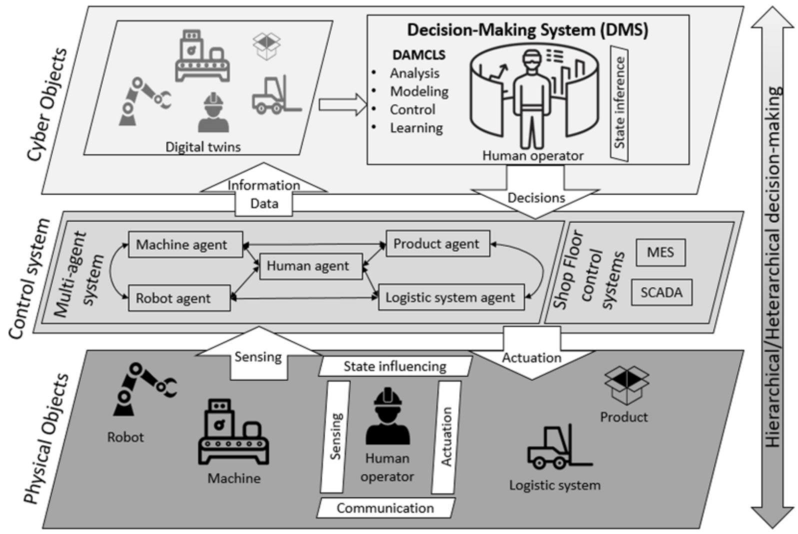

Figure 5. Social cyber-physical manufacturing system architecture integrating humans into the loop (see [45]).

Under these conditions, the social interaction with automated systems (i.e., CPS) integrates several features, like human perception, sensing, haptic interaction, or communication. When people interact with robots and other CPS there must exist some degree of awareness of the human in the loop, in terms of sensing abilities and/or interfaces and abilities of the technical system to interact and communicate with people [28,41,46].

The fact that robots with such 'cognitive' abilities are introduced in a working environment means the relation between humans and these machines also evokes the relation between co-workers and the human resource management strategies in a company [29]. Once the socialisation (the ability to interact with others, or to socialize) of the automated production systems is achieved, several scientific questions that can only be resolved through further research remain open. In particular, as the capacities and abilities of humans and intelligent systems are not similar; thus, the recognition of differences is most relevant for a balanced architecture, with a better allocation of competencies and complementarities based on new technologies as Augmented Reality, IIoT [47,48].

3.2. Social-Network Services Based Approach as a Media for Social Interaction

This second approach is based on the use 'Social Network Services' (SNS) type applications (e.g., Facebook, Twitter, Instagram, etc.) as a media for social interaction between human-human, machine-human or machine-machine. Between 1995 and 2020, a consequent raise of internet users and internet-connected devices has been observed [49,50] (« Internet World Stats » 2020) (Figure 6).

Nomadic communicating objects, such as laptops, smartphones, and tablets, have become omnipresent in our everyday life. SNS, whose development has been fostered by these devices, have been defined by [51] as "web-based services that allow individuals to (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system".

The first consequence of this rise is the generation of huge data among posing data structuration issues, leading Guinard et al. to the idea of using the structures of existing SNS to connect IoT devices into a 'Social Web of Things' (SWoT) [12] (Figure 7). The SNS's ability to collect and process data to support the creation or maintenance of social relationships between their users, is there seen as a new way to structure data exchanges within a network of intelligent connected objects (i.e., artefact agents).

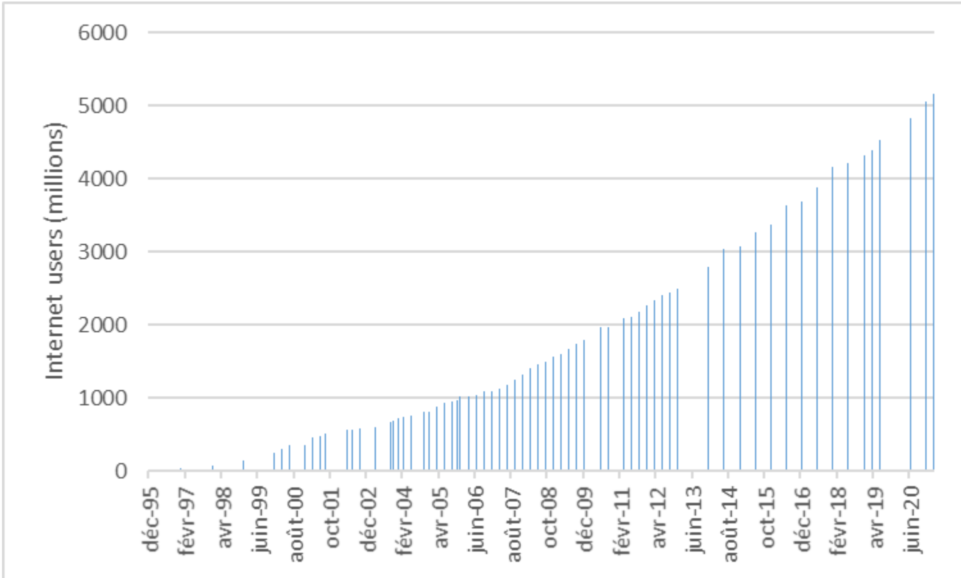

Figure 6. Internet users growth from 1995 to 2020 (according to [49,50]).

Today, this idea is fuelling the development of resilient data collection and sharing methods aiming to improve reputation, trust, and security between IoT devices [52–54] (Figure 8). These methods are based on Graphs to structure data-connection between devices, Degree distribution to quantify a node's solicitation, and Local Clustering Coefficients to group interlinked nodes as network clusters. Combining these methods to friendship-like relationships ultimate leads to a "social" SNS-based approach.

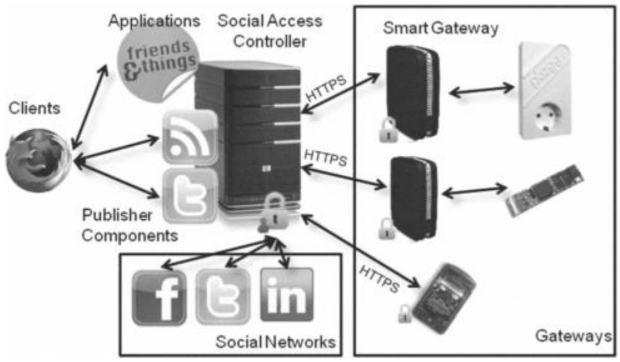

Figure 7. Social Web of Things (see [12]).

But Data structuration is not the only use that has been found for SNSs into systems' design. Social networking can equally be used as a way to organise manufacturing systems into distributed Dynamic Resource Communities (DRC) as a "new cyber-physical-social-connected and service-oriented manufacturing paradigm" [55]. This Social Manufacturing (SocialM) approach is based on the use of both socialized resources, social media, and social community inspired self-organization for resources (Figure 9).

Resource agents (here named Production Service Providers or PSPs) are interacting with each other through a global social relationship network (e.g., the SNS), enabling them to self-organize into these distributed DRC, aiming to bring resiliency and flexibility to production systems.

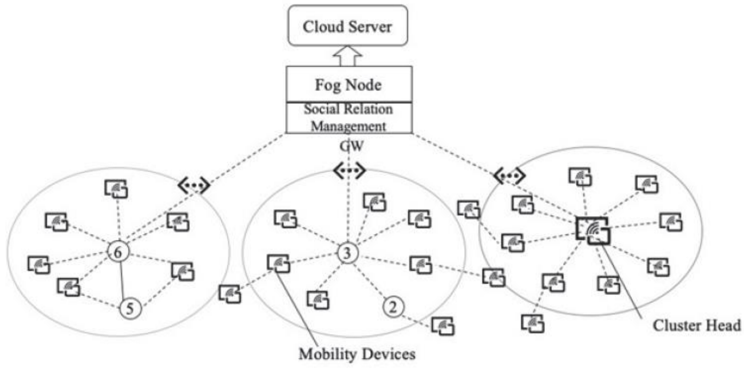

Figure 8. Data Collection Model (see [53]).

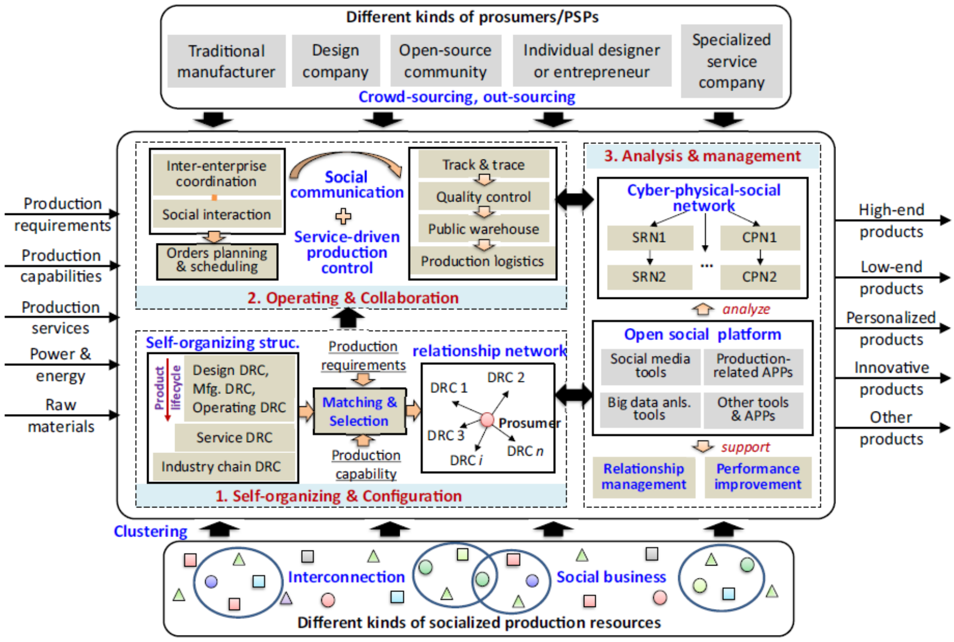

Figure 9. Logic framework of SocialM (see [55]).

The notion of social manufacturing can be found again on the work of Romero et al. on Social Factory Architecture based on Social Networking Services and Production Scenarios. They define the Social Operator 4.0 as a "type of Operator 4.0 that uses smart wearable solutions together with advanced human-machine interaction (HMI) technologies to cooperate with other 'social operators', 'social machines' and 'social software systems' to communicate and exchange information for mutual benefit and align/alter activities as well as share resources so that more efficient results can be achieved at the smart and social factory of Industry 4.0" [30].

This will increase the complexity of data management and recurrent amalgamation of roles (as today occurs with domestic bots of IOS or Google, as examples). Thus, it will be critical to understand the central role of humans in (also) complex organizational settings. The new communication tools and platforms can imply new needs of management for social relations and integrate them with connected objects through IoT. It can be imperative not to mix the functions of social media and services with humans as social actors. Together it can transform CPS systems in an "uncanny valley" already described by Mori several decades ago [56].

To conclude, social interaction will become more complex with SNS and CPS [54]. However, IA applications on manufacturing environments under the concept of Industry 4.0 should not amalgamate the function of humans as social actors. In other words, the

Operator 4.0 will remain a human and not just a “thing” connected with other cyber-physical devices.

3.3. Human-Inspired Social Relationships-Based Sociability Model: From Social Integration to System Integration

This third approach consists in a transposition of human-inspired social relationships into a technical (e.g., SIoT) or socio-technical system (associating objects and humans). Some years before, the advent of Industry 4.0, [57] noted a certain lack of consideration for human factors in the field of CPS, and developments were focused on networked and next-generation embedded systems [2,37,47]. Therefore, he proposed the concept of “Cyber Physical Social System” (CPSS) as a “tightly conjoined, coordinated, and integrated with human and social characteristics” development of CPS.

CPSS is supported by the addition of physiological, psychological, social, and mental spaces to those of cyber and physical spaces [41,58,59] (Figure 10). Written as the Word from the Editor for the first issues of the CPSS department of IEEE Intelligent Systems journal, this first approach stays conceptual, though it has been quickly followed by much more concrete works.

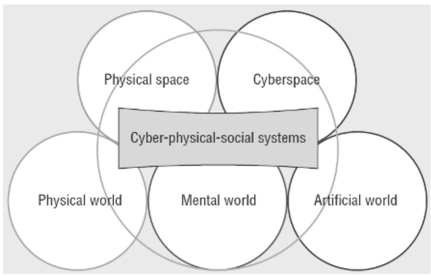

Figure 10. From Popper’s three worlds to cyber-physical social systems (see [57]).

We can notably cite the ‘Social Internet of Things’ (SIoT), developed by [60] (Figure 11). Equally based on the identification of the need to structure data into the growing Internet, the goal of this development differs from [61], for it does not focuses on the reuse of existing SNS structures, but rather on the development of a new architecture that would be “a social network of intelligent objects bounded by social relationships” [62]. This is based on 5 main social relationships inspired by human systems, such as those developed by [63].

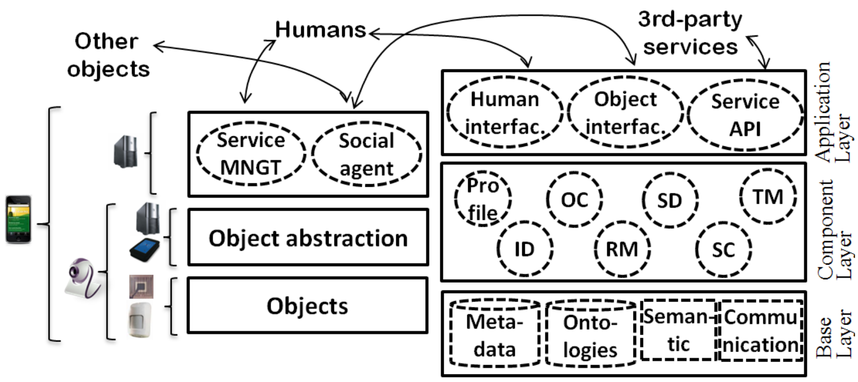

Figure 11. Architecture for SIoT: client side (left) and server side (right) (see [64]).

According to Fiske [63], human societies are regulated by four elementary forms of sociability, namely: Communal Sharing (CS), Authority Ranking (AR), Equality Matching (EM), and Market Pricing (MP). This work represents a first attempt to create a typology of social relations, which Atzori and colleagues used as a basis to develop their own typology [64]. They defined the following five inter-object relationships: Parental Object Relationship (POR), Ownership Object Relationship (OOR), Co-Working Object Relationship (C-WOR), Social Object relationship (SOR) and Co-Location Object Relationship (C-LOR).

Simultaneously, Atzori and colleagues [60,64] have developed a support architecture for object-object interactions and the discovery of services and resources within a network of connected objects. Social relationships are established and exploited among objects, but not between their human beneficiaries.

Contrasting with previous social approaches, this one relies on human inspired social mechanisms to improve the integration of purely technological systems. However, the relationships expressed in SIoT pave the way for the realization of a paradigm evoked earlier: the 'Cyber-Physical Society'. It encompasses the definition of Society 5.0 already referred above. Valette et al. [65] have proposed a transposition of those relationships to a Social Holonic Manufacturing control in CPS based factories

It was defined by Shi and Zhuge (Figure 12) as a 'Cyber-Physical Socio-Ecosystem' (CPSE) where natural physical space, social space, mental space and cyberspace interact and co-evolve with each other [59]. CPSE deals with the relationships between individuals in a cyber-physical environment and cyber-physical social system.

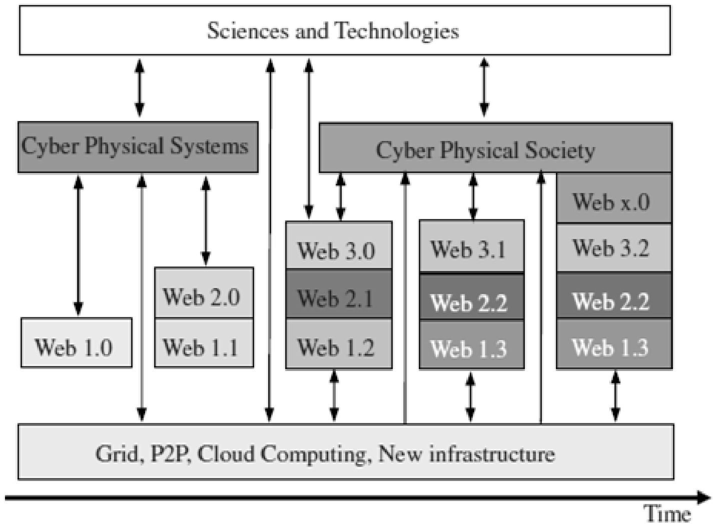

Figure 12. Cyber-Physical Society and other systems (see [59]).

If a robot, or other machines with AI can be equipped with general information about social behaviour, than it should be able to detect situations as appropriate in certain classes of social behaviours and apply them. That is specially the case when it is needed to include information about possible human operator actions in the programming phase.

With more developed devices, such capacity can also feature the intuition capacity in the interaction with humans [28]. In such cases, machines can have an autonomous "reasoning'" about how best to achieve its goals in a given social context and should have the ability to express itself in ways that will help it complete tasks in a wide range of social situations. The expression must not be verbal but can be in written forms, allowing it to be understood by the human operator.

The frames of goal achievement must be settled in work environments. In other words, the "higher the capacity is for 'autonomous reasoning', the higher must be the intuition for humans to interact with robots" [28]. This means the cyber-physical space must be designed and programmed according to the social system, for example, the one presented in a model of work organization [25,26,66,67]. In such way, we can talk about a potential symbiosis between the physical space (machinery, tools) and social space (mental references, identities, communication language, organizational roles, decision-making) referred also as Cyber-Physical Society or Socio-Ecosystem, or even Social System (CPSS), as mentioned above.

This logic is also found in the work of Pintus and colleagues [68]. These authors define the 'Humanized Internet of Things' (HIoT) as a classic machine–machine oriented IoT coupled with SIoT and the 'Internet of People' (IoP) [68]. In a manufacturing environment, the goal is to propose a social factory supporting human workers under any condition and engaging him to contribute to knowledge creation. In such a system, human, machine, and software agents would be considered as equal and provided "just in time" and "just in quality" with necessary information [14,31,46,69,70].

It is easy to perceive, behind this assemblage of paradigms, a larger vision of a socio-technical system of agents, artefacts, and human beings, organized governed by a set of social relations. Nevertheless, there is still a lot of work to be done before reaching a better acceptability of these systems, to reduce their complexity while guaranteeing their agility when facing changes of environment and to allow a better integration of the human being, either as an individual with its variabilities and as a part of a collective society through the concept of social inclusion [6,13].

4. Conclusions and Prospects

Automation has significantly increased in most production sectors, and the question remains whether there remains space for human autonomy and creativity at a working level. Does automation increase the dependency of the workers within these new systems? What are the qualitative changes of work on a shop floor level in regard to speed, expectations, demands and complexity of work? How are workers integrated into the configuration of these working arrangements? Why is the ongoing process of automation still implicitly a part of development?

Today's new technological advances associated with CPS and IoT are paving the way for the new generation of automated production systems with promising objectives of efficiency, agility, and adaptation to user needs. New levels of automation will be accomplished based on these systems with a better balance between human and machine works. This is a promise of Industry 4.0.

The purpose of this study was to explore how human/social dimensions were considering in CPS and IoT based production systems. The focus was conducted on the sociability models to ease the human social/system integration into automated production systems. The first model deals with the classical human-system interaction interfaces, where many works are done to propose new interactive interfaces or embedded sensing systems. The second model aims to take advantage of the form of existing social network services (as social websites like Facebook, Twitter ...) that offer a variety of features facilitating the socialization based on the internet. The last model relates to the design of an industrial system as a society, linking smart connected objects through a typology of social relations and paving the way to a good human-system integration.

Certainly, all these models described above have as their aim to increase productivity. At the same time, these systems increase the possibilities for intuitive interaction between humans and machines, and to contribute to ease the working conditions for operators in complex environments. The design of these elements may be a need for most automated environments that apply the concept of Industry 4.0 and articulate most CPS in production systems.

When reflecting on such automatization processes it is necessary to mention the economic, political, and ethical challenges. There are not only technical ones. The economic challenges have implications on society, and the political and ethical have a direct influence on the legal framework. Taking these issues into consideration, a number of scientific questions remain open to develop and explore future perspectives for a conscious and human cyber-physical society to reinforce the role and the contribution of industry to society, leading to, what today we name, Industry 5.0.

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References

1. Acatech. *Securing the Future of German Manufacturing Industry: Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0—Final Report of the Industrie 4.0 Working Group*; German Academy of Science and Engineering: Munich, Germany, 2013. Available online: https://en.acatech.de/publication/recommendations-for-implementing-the-strategic-initiative-industrie-4-0-final-report-of-the-industrie-4-0-working-group/ (accessed on 20 April 2021).
2. Pfeiffer, S. The Vision of "Industrie 4.0" in the Making—A Case of Future Told, Tamed, and Traded. *NanoEthics* **2017**, *11*, 107–121. [CrossRef] [PubMed]
3. WEF. *The Future of Jobs. Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*; World Economic Forum: Davos, Switzerland, 2016. Available online: http://www3.weforum.org/docs/WEF_Future_of_Jobs.pdf (accessed on 12 April 2021).
4. WEF. *The Future of Manufacturing: Driving Capabilities, Enabling Investment*; World Economic Forum: Davos, Switzerland, 2015.
5. Butollo, F.; Jürgens, U.; Krzywdzinski, M. From Lean Production to Industrie 4.0: More Autonomy for Employees? In *Discussion Paper SP III 2018-303*; WZB Berlin Social Science Center: Berlin, Germany, 2018.
6. Mourtzis, D. Simulation in the design and operation of manufacturing systems: State of the art and new trends. *Int. J. Prod. Res.* **2020**, *58*, 1927–1949. [CrossRef]
7. Autor, D.; Mindell, D.; Reynolds, E. The Work of the Future: Shaping Technology and Institutions. Fall 2019 Report. MIT Work of the Future. 2019. Available online: http://workofthefuture.mit.edu (accessed on 17 June 2021).
8. Fukuyama, M. Society 5.0: Aiming for a New Human-Centered Society. *Jpn. Spot.* **2018**, *1*, 47–50.
9. Waldenberger, F. Society 5.0—Japanese Ambition and Initiatives. In *The Digital Future*; (International Reports 1); Konrad Adenauer Stiftung (Hg.): Berlin, Germany, 2018; pp. 48–55. Available online: https://www.kas.de/en/web/auslandsinformationen/artikel/detail/-/content/society-5.0 (accessed on 17 June 2021).
10. Deguchi, A.; Hirai, C.; Matsuoka, H.; Nakano, T.; Oshima, K.; Tai, M. What Is Society 5.0? In *Society 5.0: A People-Centric Super-Smart Society*; Springer: Singapore, 2020; pp. 1–23. [CrossRef]
11. Bagheri, B.; Yang, S.; Kao, H.-A.; Lee, J. Cyber-physical Systems Architecture for Self-Aware Machines in Industry 4.0 Environment. *IFAC-PapersOnLine* **2015**, *48*, 1622–1627. [CrossRef]
12. Guinard, D.; Fischer, M.; Trifa, V. Sharing using social networks in a composable Web of Things. In Proceedings of the 2010 8th IEEE International Conference on Pervasive Computing and Communications Workshops (PERCOM Workshops), Mannheim, Germany, 29 March–2 April 2010; pp. 702–707. [CrossRef]
13. El-Haouzi, H.B.; Valette, E. Human System Integration as a Key Approach to Design Manufacturing Control System for Industry 4.0: Challenges, Barriers, and Opportunities. In Proceedings of the 17th IFAC Symposium on Information Control Problems in Manufacturing, Budapest, Hungary, 7–9 June 2021; Available online: https://incom2021.org/ (accessed on 6 August 2021).
14. Arntz, M.; Gregory, T.; Zierahn, U. Revisiting the risk of automation. *Econ. Lett.* **2017**, *159*, 157–160. [CrossRef]
15. Autor, D.H.; Levy, F.; Murnane, R.J. The Skill Content of Recent Technological Change: An Empirical Exploration. *Q. J. Econ.* **2003**, *118*, 1279–1333. [CrossRef]
16. Lu, Y.; Xu, X.; Wang, L. Smart manufacturing process and system automation—A critical review of the standards and envisioned scenarios. *J. Manuf. Syst.* **2020**, *56*, 312–325. [CrossRef]
17. Zumbado, J.R. *NASA Technical Reports Server (NTRS)*; Lyndon, B., Ed.; National Aeronautics and Space Administration (NASA), Johnson Space Center: Houston, TX, USA, 2015. Available online: https://ntrs.nasa.gov/citations/20150022283 (accessed on 20 May 2021).
18. *ISO 9241-210 Standard*; International Standards Organization, 2019. Available online: https://www.iso.org/cms/render/live/fr/sites/isoorg/contents/data/standard/07/75/77520.html (accessed on 20 March 2021).

19. Boy, G.A. Human-Systems Integration Design: From Virtual to Tangible. 2020. Available online: https://hal.archives-ouvertes.fr/hal-02424946 (accessed on 20 March 2021).
20. Vanderhaegen, F. Pedagogical learning supports based on human–systems inclusion applied to rail flow control. *Cogn. Technol. Work* **2021**, *23*, 193–202. [CrossRef]
21. Vanderhaegen, F.; Nelson, J.; Wolff, M.; Mollard, R. From Human-Systems Integration to Human-Systems Inclusion for use-centred inclusive manufacturing control systems. In Proceedings of the 17th IFAC Symposium on Information Control Problems in Manufacturing, Budapest, Hungary, 7–9 June 2021; Available online: https://ifac.papercept.net/conferences/scripts/rtf/INCOM21_ContentListWeb_1.html (accessed on 6 August 2021).
22. Lockwood, D. Social Integration and System Integration. In *Explorations in Social Change*; Zollsch, G.K., Hirsch, H.W., Eds.; Routledge: London, UK, 1964.
23. Majchrzak, A. *The Human Side of Factory Automation*; Jossey-Bass Pub.: San Francisco, CA, USA, 1988.
24. Frey, C.B. *The Technology Gap: Capital, Labor, and Power in the Age of Automation*; Princeton University Press: Princeton, NJ, USA, 2019.
25. Bril El-Haouzi, H. *Contribution à la Conception et à L'évaluation des Architectures de Pilotage des Systèmes de Production Adaptables: Vers une Approche Anthropocentrée Pour la Simulation et le Pilotage*; Habilitation à diriger des recherches; Université de Lorraine: Nancy, France, 2017.
26. Moniz, A.B.; Krings, B.-J. Robots Working with Humans or Humans Working with Robots? Searching for Social Dimensions in New Human-Robot Interaction in Industry. *Societies* **2016**, *6*, 23. [CrossRef]
27. Pirvu, B.-C.; Zamfirescu, C.-B.; Gorecky, D. Engineering insights from an anthropocentric cyber-physical system: A case study for an assembly station. *Mechatronics* **2016**, *34*, 147–159. [CrossRef]
28. Moniz, A.B. Intuitive Interaction Between Humans and Robots in Work Functions at Industrial Environments: The Role of Social Robotics. In *Social Robots from a Human Perspective*; Vincent, J., Taipale, S., Sapio, B., Lugano, G., Fortunati, L., Eds.; Springer International Publishing: Cham, Switzerland, 2015; pp. 67–76. [CrossRef]
29. Moniz, A.B. Organisational Challenges of Human–Robot Interaction Systems in Industry: Human Resources Implications. In *Human Resource Management and Technological Challenges*; Machado, C., Davim, J.P., Eds.; Springer International Publishing: Cham, Switzerland, 2014; pp. 123–131. [CrossRef]
30. Romero, D.; Wuest, T.; Stahre, J.; Gorecky, D. Social Factory Architecture: Social Networking Services and Production Scenarios Through the Social Internet of Things, Services and People for the Social Operator 4.0. *IFIP Adv. Inf. Commun. Technol.* **2017**, *513*, 265–273. [CrossRef]
31. Acemoglu, D.; Restrepo, P. The Race between Man and Machine: Implications of Technology for Growth, Factor Shares, and Employment. *Am. Econ. Rev.* **2018**, *108*, 1488–1542. [CrossRef]
32. Valette, E.; El-Haouzi, H.B.; Demesure, G. L'humain dans les paradigms de production basés sur les IoT et CPS: État des lieux et perspectives. In Proceedings of the 13ème Conférence Francophone de Modélisation, Optimisation et Simulation—MOSIM'20, Agadir, Morocco, 12–14 November 2020. Available online: https://hal.archives-ouvertes.fr/hal-03025467/document (accessed on 5 August 2021).
33. Sycara, K.P. The Many Faces of Agents. *AI Mag.* **1998**, *19*, 11. [CrossRef]
34. Schirner, G.; Erdogmus, D.; Chowdhury, K.; Padir, T. The Future of Human-in-the-Loop Cyber-Physical Systems. *Computer* **2013**, *46*, 36–45. [CrossRef]
35. Lee, E.A. Cyber-Physical Systems—Are Computing Foundations Adequate? In *NSF Workshop on Cyber-Physical Systems: Research Motivation, Techniques and Roadmap*; National Science Foundation: Austin, TX, USA, 2006; p. 10.
36. Gries, T.; Naudé, W. The Race of Man and Machine: Implications of Technology When Abilities and Demand Constraints Matter. IZA Discussion Paper Nr. 14341. 2021. Available online: https://www.iza.org/en/publications/dp/14341/the-race-of-man-and-machine-implications-of-technology-when-abilities-and-demand-constraints-matter (accessed on 4 August 2021).
37. Ashton, K. That "Internet of Things" Thing. *RFID J.* **2009**, *22*, 97–114.
38. Bordel, B.; Alcarria, R.; Robles, T.; Martín, D. Cyber–physical systems: Extending pervasive sensing from control theory to the Internet of Things. *Pervasive Mob. Comput.* **2017**, *40*, 156–184. [CrossRef]
39. Madakam, S.; Ramaswamy, R.; Tripathi, S. Internet of Things (IoT): A literature review. *J. Comput. Commun.* **2015**, *3*, 164–173. [CrossRef]
40. Monostori, L. Cyber-physical Production Systems: Roots, Expectations and R&D Challenges. *Procedia CIRP* **2014**, *17*, 9–13. [CrossRef]
41. Bao, X.; Liang, H.; Han, L. Transmission Optimization of Social and Physical Sensor Nodes via Collaborative Beamforming in Cyber-Physical-Social Systems. *Sensors* **2018**, *18*, 4300. [CrossRef] [PubMed]
42. Lu, Y.; Liu, C.; Wang, K.I.-K.; Huang, H.; Xu, X. Digital Twin-driven smart manufacturing: Connotation, reference model, applications and research issues. *Robot. Comput. Manuf.* **2020**, *61*, 101837. [CrossRef]
43. Nguyen, N.T.; Katarzyniak, R.P. Actions and social interactions in multi-agent systems. *Knowl. Inf. Syst* **2008**, *18*, 133–136. [CrossRef]
44. Sowe, S.K.; Simmon, E.; Zettsu, K.; De Vaulx, F.; Bojanova, I. Cyber-Physical-Human Systems: Putting People in the Loop. *IT Prof.* **2016**, *18*, 10–13. [CrossRef]

45. Cimini, C.; Pirola, F.; Pinto, R.; Cavalieri, S. A human-in-the-loop manufacturing control architecture for the next generation of production systems. *J. Manuf. Syst.* **2020**, *54*, 258–271. [CrossRef]
46. Efkolidis, N.; Garcia-Hernandez, C.; Huertas-Talon, J.L.; Kyratsis, P. Promote sustainability through product design by involving the user. *Environ. Eng. Manag. J.* **2019**, *18*, 1885–1896. [CrossRef]
47. Wang, X.V.; Wang, L. Augmented Reality Enabled Human–Robot Collaboration. In *Advanced Human-Robot Collaboration in Manufacturing*; Wang, L., Wang, X.V., Váncza, J., Kemény, Z., Eds.; Springer: Cham, Switzerland, 2021; pp. 395–411. Available online: https://link.springer.com/chapter/10.1007/978-3-030-69178-3_16 (accessed on 6 August 2021).
48. Baroroh, D.K.; Chu, C.-H.; Wang, L. Systematic literature review on augmented reality in smart manufacturing: Collaboration between human and computational intelligence. *J. Manuf. Syst.* **2020**, in press. [CrossRef]
49. Internet World Stats. The Global Village Online. 2020. Available online: https://www.internetworldstats.com/emarketing.htm (accessed on 20 April 2021).
50. Alam, T. A Reliable Communication Framework and its Use in Internet of Things (Iot). *SSRN Int. J. Sci. Res. Comput. Sci. Eng. Inf. Technol.* **2018**, *3*, 450–456. Available online: https://ssrn.com/abstract=3619450 (accessed on 12 March 2021).
51. Boyd, D.M.; Ellison, N. Social Network Sites: Definition, History, and Scholarship. *J. Comput. Commun.* **2007**, *13*, 210–230. [CrossRef]
52. Pujol, J.M.; Sangüesa, R.; Delgado, J. Extracting reputation in multi agent systems by means of social network topology. In Proceedings of the First International Joint Conference on Autonomous Agents and Multiagent Systems, AAMAS '02, New York, NY, USA, 15 July 2002; Association for Computing Machinery, Part 1,2. pp. 467–474. Available online: https://dl.acm.org/doi/10.1145/544741.544853 (accessed on 6 August 2021).
53. Zhukova, N.; Thaw, A.M.; Tianxing, M.; Nikolay, M. IoT Data Collection Based on Social Network Models. In Proceedings of the 2020 26th Conference of Open Innovations Association (FRUCT), Yaroslavl, Russia, 23–24 April 2020; pp. 458–463. Available online: https://www.fruct.org/sites/default/files/files/FRUCT26_Program.pdf (accessed on 6 August 2021). [CrossRef]
54. Mourtzis, D.; Xanthi, F.; Chariatidis, K.; Zogopoulos, V. Enabling Knowledge Transfer through Analytics in Industrial Social Networks. *Procedia CIRP* **2019**, *81*, 1242–1247. [CrossRef]
55. Jiang, P.; Ding, K.; Leng, J. Towards a cyber-physical-social-connected and service-oriented manufacturing paradigm: Social Manufacturing. *Manuf. Lett.* **2016**, *7*, 15–21. [CrossRef]
56. Mori, M. The Uncanny Valley. *Energy* **1970**, *7*, 33–35. Available online: https://spectrum.ieee.org/the-uncanny-valley (accessed on 6 August 2021).
57. Wang, F.-Y. The Emergence of Intelligent Enterprises: From CPS to CPSS. *IEEE Intell. Syst.* **2010**, *25*, 85–88. [CrossRef]
58. Liu, Z.; Yang, D.-S.; Wen, D.; Zhang, W.-M.; Mao, W. Cyber-Physical-Social Systems for Command and Control. *IEEE Intell. Syst.* **2011**, *26*, 92–96. [CrossRef]
59. Shi, X.; Zhuge, H. Cyber Physical Socio Ecology. *Concurr. Comput. Pr. Exp.* **2010**, *23*, 972–984. [CrossRef]
60. Atzori, L.; Iera, A.; Morabito, G. SIoT: Giving a Social Structure to the Internet of Things. *IEEE Commun. Lett.* **2011**, *15*, 1193–1195. [CrossRef]
61. Guinard, D. A Web of Things Application Architecture—Integrating the Real-World into the Web. Ph.D. Thesis, ETH Zurich, Zurich, Switzerland, 2011. Available online: https://www.vs.inf.ethz.ch/publ/papers/dguinard-awebof-2011.pdf (accessed on 4 August 2021).
62. Mala, D.J. (Ed.) *Integrating the Internet of Things Into Software Engineering Practices*; IGI Global: Hershey, PA, USA, 2019; Available online: https://www.igi-global.com/book/integrating-internet-things-into-software/210211 (accessed on 6 August 2021). [CrossRef]
63. Fiske, A.P. The four elementary forms of sociality: Framework for a unified theory of social relations. *Psychol. Rev.* **1992**, *99*, 689–723. [CrossRef]
64. Atzori, L.; Iera, A.; Morabito, G.; Nitti, M. The Social Internet of Things (SIoT)—When social networks meet the Internet of Things: Concept, architecture and network characterization. *Comput. Netw.* **2012**, *56*, 3594–3608. [CrossRef]
65. Valette, E.; Demesure, G.; El-Haouzi, H.B.; Pannequin, R. Formal and modelling frameworks for Social Holonic Control Architectures. *Comput. Ind.* **2021**, *132*, 103521. [CrossRef]
66. Tsarouchi, P.; Matthaiakis, A.-S.; Makris, S.; Chryssolouris, G. On a human-robot collaboration in an assembly cell. *Int. J. Comput. Integr. Manuf.* **2016**, *30*, 580–589. [CrossRef]
67. El Mouayni, I.; Etienne, A.; Siadat, A.; Dantan, J.-Y.; Lux, A. A simulation based approach for enhancing health aspects in production systems by integrating work margins. *IFAC-PapersOnLine* **2016**, *49*, 1697–1702. [CrossRef]
68. Pintus, A.; Carboni, D.; Serra, A.; Manchinu, A. Humanizing the Internet of Things—Toward a Human-centered Internet-and-web of Things. In Proceedings of the 11th International Conference on Web Information Systems and Technologies (20–22 May 2015); SCITEPRESS—Science and Technology Publications: Lisbon, Portugal, 2015; pp. 498–503. Available online: http://www.webist.org/?y=2015 (accessed on 6 August 2021).
69. Kassner, L.; Hirmer, P.; Wieland, M.; Steimle, F.; Königsberger, J.; Mitschang, B. The Social Factory: Connecting People, Machines and Data in Manufacturing for Context Aware Exception Escalation. In Proceedings of the 50th Hawaii International Conference on System Sciences, Waikoloa, HI, USA, 4–7 January 2017; Available online: https://aisel.aisnet.org/hicss-50/ (accessed on 6 August 2021).
70. Krüger, J.; Lien, T.; Verl, A. Cooperation of human and machines in assembly lines. *CIRP Ann.* **2009**, *58*, 628–646. [CrossRef]