

The Digitization of Manufacturing and its Societal Challenges

A Framework for the Future of Industrial Labor

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Abstract—This paper presents prospects for a human-centered design of future industrial labor in a framework depicting the dilemma between what is technologically feasible and labor-politically desirable, under the constraint of an economically reasonable design of work and technology. The analytical approach is the “socio-technical system” which assumes that new technologies will also result in personnel and organizational changes. These considerations are transformed into a framework which brings together the perspectives of human, technology and organization and ultimately leads to a complementary and ethical design of industrial labor under the conditions of a progressive digitization of manufacturing.

Keywords—*Digitization; Manufacturing; Internet of things; Industry 4.0; industrial labor; societal challenges; socio-technical system*

I. DIGITIZATION AS SOCIETAL TREND

The increasing diffusion and integration of digital technologies into all areas of societal life has experienced a renewed boost in recent years. This is because of, on the one hand, the new technical potentials that these technologies offer, and people’s acceptance and habits of use. On the other hand, new economic applications are emerging much more vigorously than ever before [1, 2]. In addition to uses in mobility and transport, energy supply, medicine and other sectors, manufacturing is a key area of application for the new information technologies. So-called cyber-physical systems (CPS) – physical machines and components networked with the Internet – are the technological basis of a dawning “industrial revolution” [3]. In an industrial-policy perspective, with intelligent automation and networks the way is opened for the advantages of extensive collaboration and economies of scale, new markets and sales opportunities, but also for far-reaching macroeconomic impetus. Thus digitization is having an intense impact, above all in many national policy programs and business strategies as a leading “narrative” of progress and prosperity [4], while being stylized by management as a “really big deal”.

This paper focusses – while sidestepping the intense technological and economic issues in the debate – on the societal challenges and consequences that arise with the digitization of industrial value creation (for a summary see [5]). It begins by outlining the German debate – carried on under the heading “Industry 4.0” – over the developmental prospects for industrial labor in Germany (part 2). In this debate are encountered the sometimes contradictory assumptions and prognoses which often overlook the formative opportunities for the future of work and employment. By contrast in (part 3) a *socio-technical* perspective is put forth for discussion, emphasizing the specific interactions of human, technology and organization and their interrelated configurations. In (part 4) this approach is condensed into a framework for the design of digital industrial labor which can realize, on the one hand, humane working conditions, and on the other, exploit the full technical and economic potentialities of digital technologies.

II. PERSPECTIVES ON THE DEVELOPMENT OF INDUSTRIAL LABOR

Many expert studies suggest that work will permanently change in all its relevant dimensions with the progressive application of digital technologies in nearly all sectors. In industry this concerns not only the activities on the shop floor, but also the indirect areas, from planning and control systems to product development, and the demands on leadership and management will also change significantly. Moreover, a thorough reorganization of inter-enterprise work and value chains is to be expected. However, the question of *how work will change* is currently being answered very differently: On the one hand there are skeptical answers, stressing risks such as high levels of job loss, dequalification, new kinds of stress and employee surveillance capabilities and thereby, increased social insecurity. On the other hand there are also

optimistic expectations of job creation, increasing qualitative demands on labor and a general reevaluation of jobs and skills, together constituting a “new, more humane turn” [4].

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This optimistic perspective and the chances of a reevaluation of labor are being discussed also in the context of the “Industry 4.0” discourse in Germany. Representative here is the position of the “Research Committee of the Platform Industry 4.0”, whose theses stress that with “Industry 4.0” are linked “multiple opportunities for a human-oriented design of the work organization” [6]. It needs no further justification to say that this is a very desirable development perspective in the broadest societal and industrial policy sense.

However, the actual realization of human-oriented forms of labor will not come about by itself. Rather, it requires a holistic and strategically oriented design approach and course of action. The model presented here will make this clear in several ways: First, there are the “social media” functions of communication and the networks between objects, machinery and human actors that are already widespread in private life and are now increasingly appearing in production and logistics. Secondly, it points to the need in the future implementation of “Industry 4.0” systems to continually take into account the socially oriented, overall context of an industrial process. More information can be found at [7].

III. APPROACH OF THE “SOCIO-TECHNICAL SYSTEM”

An analysis and design approach for this model is provided by the concept of the “socio-technical system” [8]. This concept is the basis of an ongoing research project entitled “Social Manufacturing and Logistics” (*SoMaLI*) at TU Dortmund University, Germany, a joint effort of the Department of Industrial and Labor Research (FIA) and the Chair of Materials Handling and Warehousing (FLW). The aim of the project is to develop, on the basis of interviews with experts from companies and umbrella associations, a design for the social, technological and organizational challenges of “Industry 4.0”.

In the socio-technical system concept, the issue is not one of “either technology or human”, but one of a *concerted design of a total socio-technical system*, in the account of which the structural and economic requirements of the respective field of application, and the various knowledge domains of organizations must of course be included. The defining criterion should however always be to exploit in the best way possible the potentialities of a human-oriented design.

In this concept, the total context of a production process with its subsystems *human, technology and organization* is the central focus. It deals not only with the operation and the conversion processes of the separate subsystems, but also emphasizes especially their interdependencies. Specifically, it concerns the interpretation of the functional relationships and interfaces between human, technology and an organization. The current state of research on human-oriented design of “Industry 4.0”

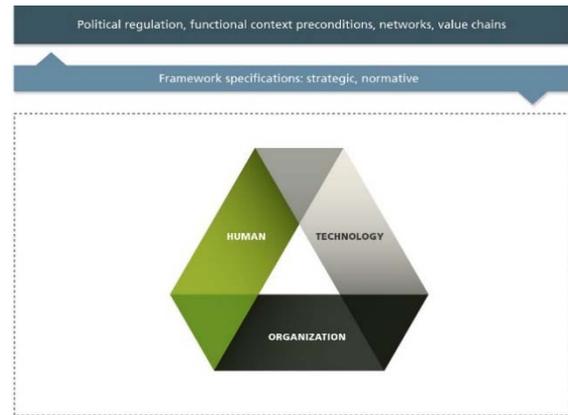


Fig. 1. The socio-technical system

systems and the empirical results from the ongoing *SoMaLI* project identify the following basic challenges:

Interface technology – human

Under the conditions of “Industry 4.0” not only the known criteria of the design of the behavioral dialogue are addressed, but the more basic issue is the question of the “distribution of behavioral responsibility” between the technological subsystem and human action. The distribution of functions between the person and the machine has to be seen as one of the fundamental challenges for the design of work in “Industry 4.0”. Here the aim is an interface design in which the human worker obtains or retains control over production processes [9] and is supported by intelligent assistance systems. The work situation is characterized by an extended range of tasks supported by “social media” functions and new requirements for qualified jobs; thus it includes the central features of a human-oriented system design.

Interface organization – human

One of the key challenges is the question to what extent human labor, through organizational design, participates most fully in the overall task, has freedom of action to maneuver, and learning and training opportunities. Because it is the organization design that ultimately determines the job description and related qualification requirements. The given freedoms of organizational design can make possible a basic positive reevaluation of all jobs and skills. Work situations may emerge that are characterized by specific qualification requirements, possibly a high degree of operational freedom and polyvalent utilization of human actors, and the various possibilities to “learn on the job”.

Interface technology – organization

At this interface, challenges emerge for the design of work in several ways: First, the level of automation of the subsystem decides what techniques will be relied on for the organizational design of (still) available functions. Secondly, due to a wide temporal and functional decoupling of technology and work, “Industry 4.0” systems offer a wide scope

for alternative forms of organization. Thirdly, under the conditions of networked systems, organizational design needs to include not only the horizontal dimension of the shop floor, but also the vertical or hierarchical dimension of the organization, as well as the supply chain. This is because the “social media” functionalities – the altered forms of communication – connect permanently such indirect areas as planning, management and engineering, as well as executive and management functions. Particularly here, the new conditions of individualized production (“lot size 1”) on the basis of autonomous, self-regulating systems need to be considered, which also in organizational regard suggests decentralized control and intelligence. In terms of a human-oriented organizational design as a whole, this signifies a turn towards far-reaching decentralization and delayering of hierarchies.

IV. CONTOURS OF A FRAMEWORK FOR THE FUTURE OF INDUSTRIAL LABOR

Thus in a first approximation, the shape of a framework for the design of digital work becomes recognizable. Following the above-outlined criteria of human, technology and organization and their interdependencies, under the requirements of “Industry 4.0” forms of work are conceivable that are characterized by the design of each of the interfaces. Criteria for the development of a human-oriented design of work should be: far-reaching monitoring and regulation capabilities, intelligent assistance systems, complete and well-generalized tasks, learnability, high maneuverability, as well as new forms of self-organization with decentralized control.

According to results of labor and digitization research, this framework addresses the social and organizational requirements for a high level of system transparency for human actors, the manageability of complex system processes, and thus optimal functioning of the entire system. The critical starting points for a human-oriented system design in “Industry 4.0” are summarized paradigmatically in Fig. 2. To conclude, we stress that such a human-oriented and therefore ethically

responsible development perspective for “Industry 4.0” is also the best way to ensure that industrial labor in the future can be suitable for an aged and aging workforce. Additionally, that it can be in great part also demanding, low stress, autonomous and therefore attractive to younger generations. Moreover, that new ways can be found to integrate (performance-) impaired employees into future systems of industrial labor.

To deal with these upcoming societal challenges leading actors in business, academia and politics should therefore explore the social and organizational conditions needed to realize the potentialities of a human-oriented “Industry 4.0” design, in order to integrate these into an inclusive socio-technical perspective.

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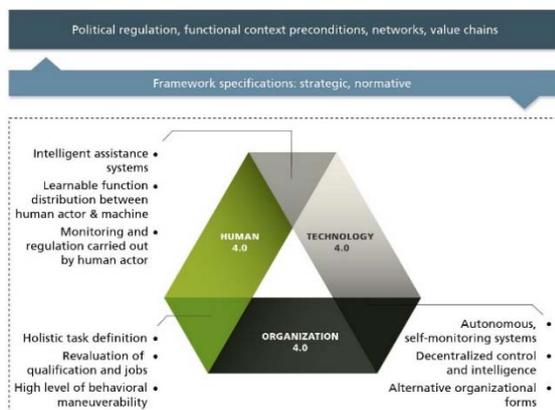


Fig. 2. Starting points of a human-oriented socio-technical system design