Special Issue Article

Capital & Class

Welcome to the machine: Human–machine relations and knowledge capture

Capital & Class
2020, Vol. 44(2) 159–171

DOI: 10.1177/0309816819899418
journals.sagepub.com/home/cnc
SAGE

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Abstract

This article discusses new technologies in regard to their potential to capture workers' situated knowledge. Machines are said to substitute but also to contribute to the labour process in collaboration with human skill sets. 'Industry 4.0' became the policy-wide shorthand to describe the new quality of real-time interconnectedness and feedback loops, known as cyber-physical systems within industry and engineering sciences. Data flows generated in these systems are used to continuously improve work processes by extracting information down to the very micro-level of neuroergonomics. In this process, workers' interactions with the system are extracted, fed back and processed for future use and improvement. The article argues that in addition to the potential for extraction of new (bodily) knowledge, shifting skill use and the potential for new forms of control, new technologies contain the potential to extract situated knowledge owned by the worker and crucial for resistance and collective struggles.

Keywords

knowledge production, labour process, machines and measures, new technologies, wearables

Introduction

Recent debates on automation are beginning to show a pattern in regard to their claims. Machines are said to substitute but also to contribute to the labour process in collaboration with human skill sets. One strand dominating the Anglo-Saxon debate is based on assumptions about future labour markets and frames automation mainly as a substitute for specific skill sets. Frey and Osborne in their now seminal paper in 2013 define jobs that are prone to automation assessing occupational skill mix using definitions used for

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national labour markets. In their predictions they rely on standardised skills sets. The contingent use of occupational skills in different companies, or across nations is not taken into account (see Arntz et al. 2016). This explains partly why consultancy firms like Deloitte and PWC have been quick in adopting the method to showcase how specific sectors like retail and manufacturing are to see massive changes in different countries. Change needs to be managed, and consultancy firms are positioning themselves to offer their expertise. The consultancy-led debate sticks to technological fetishism, not taking into account the underlying (organisational) social relations, and hence disconnects from questions around the material likelihood of automation. They neglect decision-making processes, power relations (Howcroft & Taylor 2014; Wajcman 2017), let alone gender. Even though there are new technologies at hand to increase job quality for nurses, for example, assisting robots to help carry frail people, the most implemented technologies focus on rationalising nurses work even more (Hayes & Moore 2017), or using socially assistive robots to avoid the human care work seen as necessary in ageing societies. Another obvious omission in this debate is the influence of national and sectoral path-dependency of technological developments, or precedent investment in R&D, in short a Varieties of Capitalism inspired approach to explain differences in levels of automation and future pathways.[1] Even though the World Development Report on the Changing Nature of Work delivers an insight into the challenges countries are facing, still it is reporting on an aggregated level (World Bank 2019). Last not least the integration of new technologies is by no means a plug and play situation, so the question will be what about the labour needed to integrate new technologies (Mateescu & Elish 2019) or to burden the non-intended side effects in the realm of precarious, exploitative work were 'artificial intelligence has fallen short' (Irani 2015: 721, 2019). New technologies, we can summarise so far, will be available, but it remains unclear what type of technology will become ubiquitous, what technology might be test trialled but prove inefficient and who will introduce them. The question what tasks, skills or even occupations will be automatable is contingent, but we can assume without being accused of technological determinism that new technologies will be introduced sectorwide, setting new industrial standards – as we have already seen with radio-frequency identification (RFID) chips, or scanning technologies. In this article, I will focus on changes in the relation between humans and machines at work in regard to knowledge capture. For my argument, I will focus on the dimensions seen as quasi safe spaces for human labour, problem solving and creativity, but I will frame them in terms of situated knowledge, a term introduced by Donna Haraway (1988). In this critical feminist sociology of knowledge perspective, situated knowledge captures the embodied, complicated, actively seeing part of knowledge and connects it to time and space. Opposed to tacit knowledge, the concept insists and ontologises parts of human knowledge so closely connected to the human body that they cannot make explicit. The concept follows a logic presented by Alexander Kluge and Oskar Negt (2014 [1973]) claiming that the experience of production is distinct from and incommensurable with its instruments or its product. While the related Obstinacy used within the labour process is bound to experiences, Haraway connects it to knowledge production. Hence, the question I will conceptualise in this article is how the human–machine relations are impacted by new technologies using the example of the concepts and first pilots in the context of Industry 4.0.

Industry 4.0 and the place for human labour

In its original institutional setting, the German industrial policy landscape, Industry 4.0 is defined as cooperative approach to actively steer and manage the next wave of automation (Pfeiffer 2017a). Since coined in 2011, Industry 4.0 became a proxy for all types of changes, covering all sectors, technologies and seems to be applicable in the global context from the gig economy to care work.[2] The core claim is that in actively using the skill sets available, in upskilling the existing workforce and planning future skill ecosystems wisely, automation will be a 'win win' situation. This national approach aligns the state, employer associations, trade unions and academic research institutions to transform the industrial landscape. Trade unions supported this approach, as in the ideological heart of a 'successful' transition lies the promise for a better-educated workforce, better jobs and the hope for increased job quality (Pfeiffer 2017b). However, the few publications based on empirical evidence seem to support a technological fixation, with trade unions having a say on the policy level, but workers voice vanishing in the white noise of machine talk (Butollo et al. 2018).

Empirical research suggests more negative outcomes of the newest wave of automation, with some claiming a new form of control coined 'cybernetic control' (Raffetseder et al. 2017). A cybernetic system is understood as one in which data flows are generated within a closed circuit and used to continuously improve processes by collecting and using information for further prediction. In manufacturing, for example, here understood in a broad sense including factory-like environments like warehouses, a process of 'predictive manufacturing' is enabled by the combination of analytical algorithms and data made available for processing in cloud computing spaces. While in the common use of the cloud it is reduced to its function of storing data, cloud computing and available services are the key for the next generation of cyber collaboration and real-time tracking. Cyber-physical systems (CPS), the crucial defining difference between Industry 3. and 4., have the potential to create a coupled models, 'digital twin(s) of the real machine that operates with an integrated knowledge from both data driven analytical algorithms as well as other available physical knowledge' (Lee et al. 2013: 41). This approach is used to actively monitor machines and with this human labour. Historically, data were generated, for example, for planning based on Just-In-Time systems, but the measurement took place in a way which was physically disconnected from the workers. Although their output would be monitored, the micro-movements remained shielded from view. Human labour, as shown by Labour Process Theory–inspired research was in power of reflexive and subjective agency where or when necessary, be it in the form of collaboration, misbehaviour or resistance. What we can observe now is that with machines coming closer to the workers' micro-movements, the single workers' interactions with the system are extracted, fed back and processed for future use and improvement. In addition to the potential for extraction of new (bodily) knowledge, shifting skill use and new forms of control, CPS contain the potential to extract what was often described as tacit knowledge (Polanyi 1966), owned by the worker and crucial for resistance and collective struggles.

In the following section, I will discuss in how far the new technologies allow for the extraction of worker's situated knowledge, their tacit capital, emotions and affects. The aim is to re-visit the incorporation and absorption of the human worker's knowledge conceptualised by Marx. I will then show how contrary to the linear vision of technological development underlying most debates so far, CPS re-connect the worker to the machine in a qualitatively new fashion: Human labour neither is but an appendage, nor can it strive in new realms of free time (Wendling 2011) as suggested in the earlier debates on automation, seeing the rise of system regulation (Kern & Schumann 1987) or symbol analysts (Reich 1991), in both waves described as unique and irreplaceable due to the human potential of thinking and problem-solving.

Beyond the human–machine divide: Machines and human companions

Marx's depiction of the relation between the human and the machine throughout his works can be roughly divided in a pessimistic and a more concrete utopian version. In *Capital*, Marx assumes the worker to be reduced to a 'mere appendage' doing the residual drudgery work. In Marx's (1975 [1887]) own words,

> all methods for raising the social productiveness of labour are brought about at the cost of the individual labourer; all means for the development of production transform themselves into means of domination over, and exploitation of, the producers; they mutilate the labourer into a fragment of a man, degrade him to the level of an appendage of a machine, destroy every remnant of charm in his work and turn it into a hated toil; they estrange from him the intellectual potentialities of the labour process in the same proportion as science is incorporated in it as an independent power.

The first part of the quote is in line with the negative potential of automation and the use of technology under capitalism. The human–machine relation is one-sided and weighted in favour of the machine becoming a tool to increase production but, this is important to keep in mind, also a tool for domination over the workers. One can conclude that the worker's 'intellectual potentialities' diminish in relation to the science incorporated. Marx is referencing the important connection between sciences and the development of technologies, with science becoming an independent power. In his quote, he makes one of the first and remarkable critiques on how the new and 'enlightened' sciences (not technologies!) are quickly incorporated into the capitalist mode of production. Marx presents a vision of sciences stemming from what later is called science-based industries, with the chemical industry as the first mover in this respect, establishing new links: The rise of state funded scientific research in universities, the integration of research and development into companies (or, like in the chemical industry, being the driver of the industry) and the bonds between the two. The linear idea of knowledge production never fully encapsulated the human skill involved, or could predict how workers would use them, and even the most elaborated Taylorist work system would not run without the tacit knowledge of the workers. This optimistic idea of empowerment of the workers by an ever increasing automated work organisation is emphasised by Marx. In the Fragment on Machines in *Grundrisse*, Marx offers the utopian vision of technology freeing up time, with machines mirroring advances in sciences and hence literally incorporating while at the same time allowing for what he called the general intellect of the worker to rise (Marx [1857]). In the post-operaist perspective, the then remaining immaterial labour (affective, emotional, but also control and regulation of the machines) would be disconnected from measured (or: Measurable) time, with value creation collapsing into fixed capital. This process would be crucial to build on the hope for the 'social worker' and the rise of a new revolutionary subject. While the debate around the general intellect and immaterial labour is advanced (see Thompson & Briken 2017 for a critical discussion), for my argument, I am more interested in the way in which Marx conceptualises the relation between sciences and human labour, knotted together by knowledge. As mentioned earlier, one crucial point is not control for the sake of control (and often confused with surveillance). Control in the Marxist version is a broader concept including the control with regards to knowledge. Wendling (2011) made an interesting point in carefully reading through Marx's work in regard to his vision on the role of sciences. The ownership of knowledge on the one hand seems to lie fully in the hands of what Taylor described as 'scientific management'. This version of separating the human worker from the machine within the labour process resonates with many of the debates concerned with the introduction of new technologies at work. The polarisation thesis (Kern & Schumann 1970), or the (contested) deskilling thesis (Braverman 1974) agreed on the fact that the job design of low-skilled routine work in manufacturing would lack autonomy and reduce worker's cognitive powers (Spencer 2018: 2), while highly automated workplaces would have the potential to use different skill sets. In the 1980s, the notion of system regulation captured this idea suggesting workers would be freed from direct machine-related tasks. The question about the 'Limits of division of labour', as launched by the German industrial sociologists Kern and Schuman in 1987, resonated with 'flexible specialisation' (Piore & Sabel 1984) and other far-reaching predictions based on case study research, leading to the idea of creating automation winners and losers, a notion that tends to guide media coverage and policy advice until today. The rather reductionists and binary perspective on the development on human–machine relation reflects how, within the sociology of work, so far machines and human are still predominantly conceptualised in a way that seems to allow to objectively assess and separate skills use from the tool. Or, in other words, as if the boundaries between the human worker and the machine tasks can be set based on scientific measurement and calculation.

However, with and against Marx, his draft on the Fragment of Machines offers the option for a more nuanced reading, taking into account the excess knowledge deriving from, but at the same time and more important for the sake of this argument, created within the interaction between human labour and the machine: From an engineering or management perspective, these pockets of autonomy and discretion are seen as the cause for errors in an objectified 'rationale' workplace, or as flaws in the workings of technology; labour process theory conceptualises the potential for some forms of resistance and organisational misbehaviour around situated knowledge (Ackroyd & Thompson 2016; Thompson 2016); literature inspired by post-operaist perspectives tend to focus on the immaterial aspect of labour and emphasise emotional and affective labour to allow for the workings of the machinery to their full capacity. While these strands describe the human–machine relations in an opposing way, separating the human distinctively from the machine, it is worthwhile to remind us of the workers' perception of the relation to the technologies. On the one hand, research on occupational and work identities has not only shown the relevance for workers' identity but also for collective struggle and as part of workers' power (Briken & Taylor 2018; MacKenzie et al. 2017). On the other hand, studies in the sociology of work and subjectivity have long suggested that even in so-called unskilled and routine work environments, subjective factors like 'emotions, sensations or impressions derived from personal experience' (Pfeiffer 2016a) play an important role within the labour process (p. 5). This specific strand of studies on experienced-based work is partly overlapping with ideas around tacit knowledge. However, the focus here is on the analytical level, focussing not on tacit knowledge in general but more on what Haraway has described as situated knowledge and the connected emotional and affective encounter with technology, blurring in part the frontier between human and machine. One example from earlier days of automation would be research done in control rooms in the chemical industry. Workers no longer had direct contact with the production process but worked spatially separated in what was called the 'second reality of production'). Here, researchers found that sometimes workers would ignore an alarm; and how they would run immediately the next day with the exact same alarm getting off. When asked, the workers would reply how they would 'sense there is something wrong'.[3] The Eigen-Sinn of the machinery, with workers addressing the machinery as a quasi human, investing care and emotions or even affect is what makes even routine assembly work prone to the unpredictability of machines and humans, only understood by the human worker (Pfeiffer 2016a).

The new management concepts discussed above focussed precisely on closing this knowledge gap by switching from (individual) company suggestion schemes to (collective) continuous improvement processes. A common feature of all variations of 'lean' or Toyotism was to 'dig in the gold of worker's brains' and the connected responsibilisation of workers and teams to improve their work environments. Instead of skills, human resources management started focussing on workers' knowledge, and specifically the ones hidden so far, labelled tacit knowledge (Nonaka & Takeuchi 1995) These concepts aimed at depicting even the smallest potential for incremental innovation. They also promised to improve job quality and increasing workers voice; enthusiasm quickly curbed by management. Today, improvements delivered by semi-autonomous work groups and individual workers are part of performance management schemes, and strong pressure is put on workers to disclose their situated knowledge.

Beyond control: Capturing situated knowledge

The normalisation of incremental innovation from exceptional and expert tasks to daily routine on the assembly line was closely connected to the widespread integration of information technologies into companies in the 1990s. New forms of enterprise resource planning (like the then famous SAP R/3 software) gave firms the opportunity to coordinate all resources, information and activities needed to complete their processes, from order fulfilment, billing, human resource management, to production planning – but in real time and, if necessary, visible for everyone. This new mode of rationalisation, coined 'systemic' in the German context, enabled the organisations to focus on the entire value-added process, or, value chain. The point I want to highlight is the availability of 'objectified' measurement shape shifting the mode of control. The newly available real-time data had the potential to put organisational units down to the very team level under the pressure of actual or fictive market forces (Sauer & Döhl 1994), changing the quality of performance management towards the 'objectivation or de-subjectivation of performance politics' (Sauer & Döhl 1994: 212, translated by the author). The shift towards data-driven forms of control enabled a new time economy – known as Just-In-Time – ultimately intensifying work. The potential for measurement also enabled to encourage competition at group and individual workers level. In essence, workers, no matter their skill levels, were subjected to more extensive and objectified forms of control. This process can be covered with what Edwards (1979) characterised as technical and bureaucratic control, that is, the capacity of the technology to pace and direct the entire production process and to objectify control. However, the inclusion of markets as controlling forces brought in at least a new legitimation stemming from outwith the organisation.

From the mid 1990s onwards, the potential to gather real-time insight into all inter- and intra-organisational processes increased exponentially. Benchmarking, that is, comparing ever more and sophisticated layers and levels of the labour process, teams with teams, but also with industry-wide metrics became standard and a newly normalised management function. The increase in visualisation and transparency and the pressure on workers to integrate their knowledge by continuously contributing to make their workspaces more efficient, hence to add even more surplus value in the same amount of time, the real-time data also turned into a tool for workers' self-control. Far from being 'chimeric', as suggested by a poststructuralist reading of the labour process and control, workers know exactly the extent to which they are controlled. Visualisation was one of the key changes on the shop floor, rarely discussed in the debates around lean management and high performance work systems. In car manufacturing, control panels operating in view above assembly lines, for example, would indicate the real-time outcome of each specific point or workplace at any given time of production. Workers only needed to raise their heads to see how much they had produced, what they were supposed to and how their outcome matched compared to other shifts that day or that week. Continuous improvement in many of these work systems became an integral part of performance management. The aim was to extract the workers' situated knowledge, and hence to eliminate the 'waste' embedded in workers' reflexive agency. Although spaces for resistance and organisational misbehaviour would be harder to sustain, labour process–oriented research still opposes for good reasons the idea of technology determining every pore of the working day. Surveillance might have become ubiquitous, but the connected forms of control still relied very much on feedback on outcomes, hence on static data, not the process. The direct impact of technology on the worker and vice versa was as yet unopened Pandora's Box, and improving performance relied either on planning outside the workplace, or the active collaboration of workers.

It is important here to distinguish between different management interventions to improve performance and increase the surplus value of human labour, one focussing on skills utilisation, the other focussing on knowledge extraction. The first can be considered as suggested by O'Neill, with an approach trying to make use of the full skill set of the workers, including their psychological and bodily functions (O'Neill 2017). The impact of cognitive and behavioural sciences in this area was on the rise at the very moment at which progress in specifically neurosciences started dominating the perception of the human body, and psychological status was considered as something that can be transformed into mind-sets. This hyper-positivist turn in psychology led to the study of what is called neuroergonomics, defined as the study of brain and behaviour at work to align technological and human capabilities with the aim to increase efficiency. The development of non-invasive technologies and their wearability include the potential 'for monitoring human brain function that can be used to study various aspects of human behaviour in relation to technology and work, including mental workload, visual attention, working memory, motor control, human-automation interaction, and adaptive automation' (Parasuraman & Rizzo 2007; Radüntz 2016).

Cognitive and behavioural sciences no longer relied on collected experimental knowledge – they now had real-time feedback loops. In an introduction to a book on 'Automation and behavioural sciences' the author states that

> (t)he tremendous increase in automated systems in the workplace seems to have caught the behavioural sciences unprepared. Despite the almost common place use of automated systems in a variety of occupations, there is only a small body of literature that has discussed the effects of these systems on performance. In fact, it is only recently that social scientists have turned their attention to this important aspect of performance. Consequently, the need to understand the degree to which automation affects human performance in complex systems is becoming an urgent topic for applied scientists. (Mouloua 1996: 21)

With ever more developed technologies, the factory planner and work designer have more and more tool available to overcome the obstacles of planning efficiently by surveilling workers agency. The few papers engaging with this topic so far (Lemov 2018; Moore 2018; Moore et al. 2018) suggest that there is a strong continuation between early time-motion studies (inspired by Taylor and Gilbreth) and the human relations approaches (Mayo, Müntzberg). However, in this perspective, the binary division between mind and muscles inspired by Taylor seems to be reproduced. New technologies seem to be solely used to further control workers, and to monitor new, so far invisible, and subjective information about the worker. The idea of 'finding the right man for the right job', based on physical capabilities, simply seems to be expanded to emotions and affects to be included to assess performance (Moore et al. 2018). New technologies quite rightly measure the impact of environmental influences on performance and predict the areas for change, the worker becoming 'agile' just as the work system (O'Neill 2017). But what about capturing the situated knowledge? Empirical research so far has not fully engaged with the involvement of workers in continuous improvement processes as part of today's performance management and target-driven work organisation (Taylor 2013). In the last section, I will present some preliminary findings from research within the German context and discuss the suggestions on how to conceptualise what is known so far. In particular, I focus on the concept of 'cybernetic control' (Butollo et al. 2018) and how the value capture of situated knowledge might change within cybernetic work systems and their ability to record, process and feedback data down to the micro-ergonomic level.

Welcome in the machine: Towards cybernetic control?

While there is some empirical evidence for changes in manufacturing in the realm of Industry 4.0 (Pfeiffer 2016b), the implementation and use of wearables and real-world CPS is in its embryonic state still. In a recent publication focussing on how solution developers and management frame and legitimate the implementation of new technologies, Evers et al. (2018) can show that the interviewed managers, though also driven by the idea to increase efficiency, clearly engaged with their projects due to the incentives and initiatives by the German government. With pilot studies funded and evaluated by independent researchers, companies could showcase their innovative culture. New technologies in this respect seem to be seen as a new 'must have' rather than fully integrated into management process thinking so far. On the other hand, software developers were eager to marketise their new products in underlining the benefits for the workers and selling it to companies promising 'significant gains in ergonomics and production efficiency (that) can be achieved when work process data is recorded and analysed comprehensively' (Evers et al. 2018: 18). They also outlined new forms of labour control, and 'mentioned cases in which the technology would recognise whether the employees showed up the first day after their holidays, or whether they are currently working on a piece that was no longer a part of the production program' (Evers et al. 2018). Software developers than pointed out how isolating the use of new technologies could be specifically in regard to the possibilities to communicate. Evers at al. (2018) present the following quote underlining some of the potentials of wearables 'Of course, I now have to say that I no longer have to walk to the control room, and I cannot talk to my buddy in the control room anymore – yes, actually that's an issue'. (Solution Developer, Germany LE-D-4). Decreasing autonomy and self-responsibility – pillars of high performance work systems – seem to vanish, and so might the space for workers resistance. These conclusions are supported by the findings presented by Butollo et al. (2018) with the example of so-called 'smart maintenance' approaches based on predictive maintenance concepts. They can observe a shift in the perception of how workers' skills will be deployed. With systems now based on data analytics, maintenance personnel is reduced to simple tasks like exchanging parts in a prescribed way. In their report, this is described by one interviewee as the fading away of the 'machine whisperer' (Butollo et al. 2018: 15). What is to be observed here is the change in occupational identity, but also a loss of collective power at work. Butollo et al. (2018) furthermore stress how the underlying assumptions are based on a strong 'technology-fixated' approach to the implementation of new technologies. Organisations, as they see it, would be in danger to lose the capacity for human-led problem-solving potentials in the case of system failure by cutting away experiential, or, as I would frame it, situated knowledge (Butollo et al. 2018). While the authors focus on how trade unions and workers' councils could engage with these challenges in pushing for participation-oriented approaches, Raffetseder et al. (2017) suggest to frame the use of new technologies with a new form of control. As mentioned in the introduction, they see 'cybernetic' control in the making, where top-down and outcome control is horizontalised and integrated in the immediate workflow. Yet again, the potential of new technologies is underestimated when focussing on control, autonomy or discretion only. What is at stake is the equivalent of the passing of situated knowledge to the next generations of workers, that has been a process harnessed by capital for years, to create an ever more exchangeable workforce. In how far this crucial point of resistance for workers can be upheld, how actually existing workfare systems favour this type of work organisation (Briken & Taylor 2018) and what this means for further collective action and strategies clearly needs some further empirical grounding. But it seems important to take into account that new technologies have at least the potential to increase efficiency with workers involuntarily while working, delivering the necessary information. The workers very own interactions with the system they are included in are extracted, fed back and processed. Workers' situated knowledge, their tacit capital and emotions and affects are more likely to be recorded and analysed for future use and improvement (either on site or in factories elsewhere). The integration of new technologies hence obscures how the transformation of labour into labour power is actually taking place. Neither is there any directability of the machine, nor observability (Morison & Woods 2016) on what the 'machine' is doing or learning from their moves or affects, let alone how they contribute to improving the work system.

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Notes

1. At the time of writing this article, we can observe a striking renaissance of national industrial strategies connected with the debates around 4.0 in Western European countries, and it would be worthwhile to consider the upcoming varieties of automation in the specific national contexts and how they might be considered as supporting the rise of nationalism (Briken et al. 2017).
2. 4.0 relates to a linear version of industrial revolutions, the third being defined by the use of IT and ever more automated production. Although seeded within a paradigm based on manufacturing, the idea of 4.0 spread into services, with ideas like Business 4.0 (Volkswagen), Skills 4.0-Initiatives (Skills development Scotland) and Japan even moving towards a Society 5.0 already.
3. This observation was confirmed by my own empirical investigations and workplace observations on the shop floor in the German Chemical Industry between 1997 and 1999.

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