CPS and the Worker: Reorientation and Requalification?

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1 Enter the Process Worker

In his book about the "rationality" of economic reasoning, the French theorist André Gorz referred to an analysis of the "process worker" that had been published by an individual using the pseudonym "Ilnox" in the communist daily "il manifesto". The process worker, explains Gorz ([19], 111ff.) citing Ilnox, is the by-product of computerization, which represents a new interface between the production process and the worker. The skilled and unskilled worker of the production line will cease to have any physical interaction with the product, but will now focus mainly on controlling and maintaining the production process. Thus, computerization will impose its own standardizations, such that the kind of work done, irrespective of its location or even industry (brewing, power plant, pasta production …), will essentially be the same—monitoring and controlling the production process at a distance, via display screens. The effects of this transition for the process workers will be hard to underestimate and somewhat contradictory: first of all, the monitoring and controlling tasks, and the context skills needed to complete them, will be somewhat more complex than the current tasks and skills, so some re-skilling will take place. Secondly, these skills will be accessed more easily and will be transferable across more or less all industries and locations, giving the process worker more mobility. At the same time the skills in use may be rendered

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commonplace, because few company or industry characteristics will be relevant, giving the process worker little advantage over others in competitive situations. Finally, the work to be done will be quite dull. Monitoring events might call for action sometimes, but they will mostly require passive observation. The worker will create nothing, but this nothingness will drain him. Interestingly, Gorz did not view this development too negatively: It will at least free the worker from hard, physical labour and give him a chance to counter balance dull activities with a rich private life outside the factory (ibid, 148).

This development and Gorz's conclusion might be surprising to some extent, but it appears to be the climax of a consistent chain of events. For the longest time, machines competed with man on efficiency. Instead of automation being designed in such a way as to use the skills of the worker, man was increasingly degraded and being fitted into mechanized processes ([14], 259, [10]). Finally this battle seems to be over. Men—so it seems, must go elsewhere in search of identity or even humanity, as Moravec ([26], 134ff.) added with a twinkle: labour is such a minimalist goal!

2 The Opening of the Lights-Out Factory

The goal has always been to remove humans from the production process ([27], 333). The course of this path taken had economic but also political reasons:

> The idea of replacing humans with machines was nothing new, of course. From the Great Depression, through the war, and into the Cold War, the nexus of labor and manufacturing technology was a continual source of both innovation and conflict. […] in 1948, there was widespread concern among the U.S. business elite that organized labor had become too powerful: Union membership had soared during the war, as had the number of strikes. Many in government and industry also worried that the United States lacked the industrial might of the Soviets. Clever, electronics-infused, self-guided machinery promised a solution to both concerns. [11]

In some instances we seem to have reached this goal. The most striking example is the lights-out factory: a production plant so completely automated that robots could turn out the lights by themselves (a very unlikely prospect, as these factories can and should work 24/7). The first examples of this kind of production facility are quite impressive:

> The brightly lit single-story automated shaver factory is a modular mega machine composed of more than 128 linked stations-each one a shining transparent cage connected to its siblings by a conveyor, resembling the glass enclosed popcorn makers found in movie theatres. […] Each of the 128 arms has a unique 'end effector', a specialized hand for performing the same operation over and over and over again at two-second intervals. One assembly every two seconds translates into 30 shavers a minute, 1,800 an hour, 1,304,000 a month, and an astounding 15,768,000 a year. ([25], 66f.)

In this factory, the role of humans is minimized and seems to even exceed Gorz's vision of the process worker:

> Meanwhile, a handful of humans flutter around the edges of the shaver manufacturing line. A team of engineers dressed in blue lab coats keeps the system running by feeding it raw material. A special 'tiger team' is on-call around the clock so no robot arm is ever down for more than two hours. Unlike human factory workers, the line never sleeps. (ibid, 67)

The workers in this plant are, obviously, concerned with controlling and monitoring, although it seems this role will also be taken over by machines sooner or later; the robots themselves already know how to sort out mistakes. The system is therefore tolerant of small errors. Thus, not many workers are needed at all in this kind of factory—in our example it was less than 10 (ibid). The lights-out factory, so it seems, has already surpassed the need to interact with humans intensively:

> Many of the new production methods in this next revolution will require fewer people working on the factory floor. Thanks to smarter and more dexterous robots, some lights-out manufacturing is now possible. FANUC, a big Japanese producer of industrial robots, has automated some of its production lines to the point where they can run unsupervised for several weeks. Many other factories use processes such as laser cutting and injection moulding that operate without any human intervention. And additive manufacturing machines can be left alone to print day and night. [35]

3 What Skills Now?

As the role of the workers in CPS-dominated production is rather questionable, if not marginal, it should come as little surprise that views about the kind of workforce and skills needed, are rather vague ([30], 9ff.). Consequently, and rather in line with Gorz's vision of the process worker, the idea that humans are mainly there to fix errors and to interfere with the CPS if distortions occur seems to be the common ground ([18], 527, [31], 9f.). In a rather comprehensive view on qualifications for CPS-dominated work processes, Pfeiffer [30] is quick to explain that not only monitoring skills are needed but that the nature of the process workers requires a huge amount of "working capacity", that is skills that are needed in order to fix things when needed. This is also in line with Gorz, who conceded that the process worker seems to have long phases of monotonous observations intermingled with hectic phases of problem management. Recalling the picture of the lights out-factory, we should now suspect, however, that this error fixing should pretty quickly surpass the generic skills of the process worker, as detailed and sophisticated knowledge of the production process and the robots would be required. However, Pfeifer, who develops a comprehensive overview of the required skills of the worker in CPS-intensive processes, reaches the conclusion, that the majority of new skills will probably lie in the area of data management, data privacy and data security (ibid, 26ff.). In contrast to Gorz, she furthermore assumes that the company specific characteristics she describes as the "offline side" of the CPS production will become more important: Anything that cannot be fitted into given data structures but that remains important for the production process (ibid, 33); although at this stage, we are left to wonder what this company specific knowledge might be.

4 The (Temporary?) Return of the Gods

In a provocative claim, the science fiction writer and computer scientist Vernor Vinge put forward the notion of a computing singularity in which machine intelligence will make such rapid progress that it will cross a threshold and then, in some yet unspecified leap, become super human ([25], 9pp.]. If Singularitarians are right, this transformation will lead to human labour becoming surplus: There will be fewer places for human beings in the resulting firms and economy. This has certainly not happened yet [22]. A remarkable company policy shift that suggests that there are limits to automation was the recent decision of Toyota to systematically re-integrate humans back into the production process.

> After pushing its automation processes towards lights-out manufacturing, the company realized that automated factories do not improve themselves. ([25], 90]

The return of the extraordinary craftsmen, known as *Kami-sama*, or gods, who, in the traditional company, had the ability to "do anything" with a focus on improving the production process, points to another important role for the worker: not only supervising the automated production process but also serving as a kind of "role model" for the robots and production lines:

> These gods […] are making a comeback at Toyota, the company that long set the pace for manufacturing prowess in the auto industry and beyond. Toyota's next step forward is counter-intuitive in an age of automation: Humans are taking the place of machines in plants across Japan so workers can develop new skills and figure out ways to improve production lines and the car-building process. [37]

From this point of view, the robots and production systems must learn from humans, requiring refined and extraordinary workers who possess deep skills to be recreated in machines:

> 'We cannot simply depend on the machines that only repeat the same task over and over again,' […] 'To be the master of the machine, you have to have the knowledge and the skills to teach the machine'. (ibid)

Singularitarians, of course, would argue that this is a mere interim partnership between humans and robots, during which human knowledge is transferred, and at some point, creativity will be transferred too or will even arise on its own in some brilliant machine of the future ([25], 90). After all, the self-learning machine was the starting point of Silicon Valley [11].

For now, however, there is quite an intriguing point to make: The process worker model falls short in describing the role of humans in modelling robots and CPS assembly lines ([17], 54). The skills needed here are not only the average skills, those easy to access and to transfer, but also deep skills in all the moves and steps needed to assemble the product. Here we find the overlap between the off- and online world of CPS production: Companies that manage to re-create sophisticated human skill levels in their machines and robots will become superior to others that are less

capable, as is the case in IT programmes that are better than others, although the same technology and programming language is in use.

5 The New Factory: Connecting the Dots

The often vague and general character of some views on the skills of the factory worker might have to do with the fact that observers sometimes implicitly assume that the factory will continue to exist in its present state in the future. There is, however, little reason to believe that production lines will change dramatically while leaving the factory structure as it is. Sometimes, scholars perhaps overlook that in linking up and interconnecting machines, robots, supply stores and customers, CPS will create opportunities for "opening up" the value chain of the factory to actors outside the traditional boundaries of the organisation [32, 34]. The significance of this development has to be understood against the backdrop of a hitherto de facto "closure" of factories:

> […] to make their just-in-time manufacturing work, Toyota limits the number of suppliers that it deals with and tightly integrates its operations with these suppliers […] In other words, Toyota has been able to achieve high flexibility in its operations by closing its system and limiting the diversity of participants. ([20], 81f.)

Now, CPS will be key in enabling totally new configurations of producers, suppliers and customers. This new setting has been labelled "Open Manufacturing" and should be considered the organisational twin of CPS (see Fig. 1).

If the experience of the well advanced and already considerable "open" IT industry is any indication, than the product of the Open Factory will be a combination of publicly available parts (commons) and proprietary enhancements [38]. This mix will cause a massive disruption for the production line worker: the openness of the product and the factory will be determined by the flexibility of the production line and will ultimately constitute the company's comparative advantage and value creation ([12], 21ff.).[1]

In this new mode of production, different producers work on products that are open in the sense that their patent is public (Tesla) or that standardized and open interfaces to the product (API: Application Programming Interfaces) are available and developers are invited to participate in the development of applications (Watson Cloud). Thus, even developers outside the current boundaries of the factory have access to the product blueprint and participate in its refinement and ongoing development (hacking). These developers sometimes labelled Tinkerers can also collaborate with each other using open working spaces (Fab Labs) that are connected and drawn to the Open Factory to elaborate their ideas, evaluate and improve the

[1] As it has been pointed out, the value of CPS does not rest in the mere connection of different elements of production. In addition, the CPS enabled assemblage will create additional functionalities (and value).

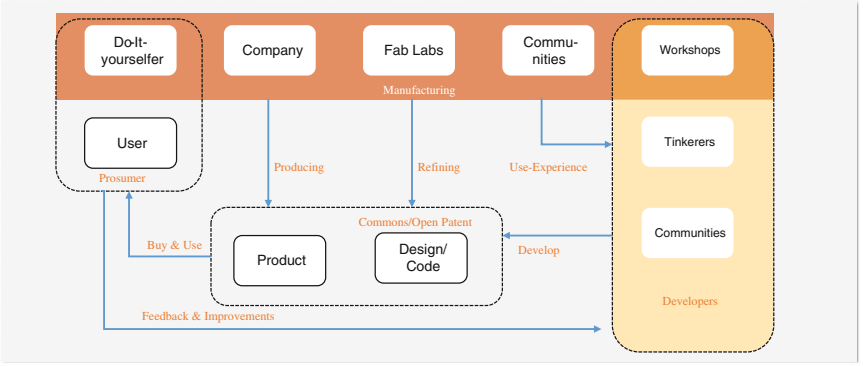

Fig. 1 Open manufacturing. *Source* ([7], 195)

designs of others and participate in the production process ([6], 59ff., [33, 36]). The tested designs would then be sent to the production lines to be "printed out", if the series is large enough or being replicated in a decentral manner using 3D printers.

It is obvious that working as a production "worker" in this kind of environment would be quite a different task than in the lights-out factory. Not so much because the physical production is different in principle, but because this production needs to be connected and reconfigured to cope with different kinds of design inputs and manufacturing options [2]. The production worker in this setting, thus, will embrace more "design thinking instead of production thinking" ([9], 12). In this context, some of the typical digital buzz will make more sense:

> A lot of collaborative and cross-cultural competencies will be required to be able to work in network environments sustainably. On the technical side: connecting the network will mean a lot of standardization. Therefore, the technical competency profile will be rather T-shaped and interdisciplinary than specialized. Analytics specialists will have to work across business models, production processes, machine technology and data-related procedures. (ibid, 13)

By introducing the Open Factory concept into the analysis, a vast array of new skills and tasks now comes into consideration (see Fig. 2).

The "worker" in this setting will need knowledge about the elements of the CPS enabled production that need to be reconfigured: adequate machinery (all-purpose open source MultiMachines, prototyping …), on demand infrastructures (online 3D printing services, Design for download …), Internet of Things (trackable objects, Sensor Commons …), Open Development methods (modularization, open development, crowdstorms …) and social movements (Maker Movement, Open Source Development, Hardware Hacker …). Thus, the worker

> […] will set up determining factors of production, design, install and maintain complex cyber-physical systems and define the rules of production […]. ([32], 7)

The knowledge about those elements will enable him to constitute the "factory" according to the specific requirements of the product and marketing strategies: The "factory worker" evolves into an enabler or architect of the open factory.

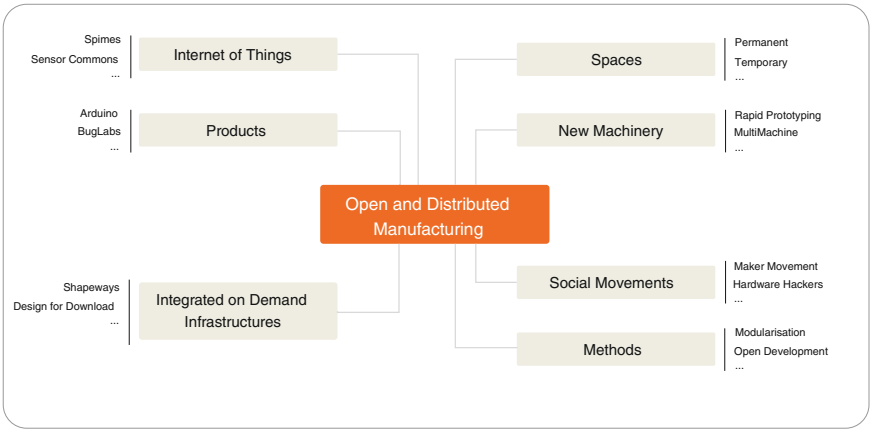

Fig. 2 Skills and tools of open manufacturing (excerpt). *Source* ([7], 210)

6 Worker and Management: Converging Roles?

The new tasks of the "worker" that have been suggested here, obviously have little to do with the original concept of the factory worker. But the changes do not stop here. If we extend Gorz's argument, we can anticipate, that via the influence of ubiquitous social media, automatization and the opening of the work structures enabled by CPS, a kind of convergence of skills, tasks, roles and ultimately profiles in the workplace will take place. Thus, not only will the tasks and skills of "workers" be related *between* different industries, but the many roles *within* the factory may to a relevant extent assimilate as well, at least at the task and skill level. If work will be done mainly using virtual interfaces, (organising production lines, organising customer communities, communicating to employees …) than we can reasonably expect rather similar skills in the new factory across many roles and levels, perhaps even to the extent, that the traditional schism between worker and manager will become less important or even obsolete ([3], L2f.). At least—if we do not wish to engage in the discussion of converging roles and levels we can concede that workers will become more "empowered":

> In a more interlinked world the function of employees will shift away from simple operators towards decision-makers that are actively involved in the decision making process, which focuses not on selective optimization but also considers the overall contexts. ([32], 7)

Of course, there will be specializations, in the sense of roles having different focal points (organising employees, customers or production lines) and deep unique expertise at various points, but the tools used and the resulting profile requirements will be analogous: the digitization of work will lead to an abstraction of different functions and tasks, with the consequences that they will be quite similar although

they will have different ends (i.e. addressing customers and connecting producers via the same technology).[2]

At this point, we can only vaguely speculate on what this convergence would mean from the perspective of an economy based on division of labour and specialization. We need to consider that automation hitherto was mainly being used as to reinforce the role of management.

> Automation was designed through the state system to demean and degrade people to de-skill workers and increase managerial control. ([14], 259)

History reminds us, that existing power structures will not be overridden by mere technological advancement or inexorable market forces ([24], 63ff., [28], 3ff.) But structures and institutions are rather shaped according to the political will of the involved actors and parties that—paradoxically often attempt to rationalize their strategies ex post as the best economical or technical solution: might makes right ([29], 151ff.). Although the outcome of this transformation process is therefore highly uncertain, as small actions by groups here and there may shift the vectors and the institutional forms in radically different directions, there are already indications that stakeholders are recognizing this alteration of the power bases, and the first realignments and regroupings seem to be taking place ([4], 11ff., [39], 132).

7 Conclusion: Moving up the Ladder

Starting from the first perspectives of the 1980s, covering current developments and also anticipating the factory of the future, there are three possible models for the human in the CPS production line:

- *The process worker*: This worker is mainly concerned with monitoring the more or less fully automated production process. This rather limited role is the end point of a development that wishes to eliminate humans from the production;
- *The role model*: This role brings back the human as a template for mechanical skills that need to be reconstituted in machines. The human here becomes an extraordinarily skilled and versatile worker, who works in enclaves (workshops) to retain and refine skills that are not used in the production process directly, but will be transferred to the machines in order to gain the upper hand in the configuration of the production process and to maintain competitive advantages;
- *The architect*: Here the factory worker becomes the enabler and configurer of the CPS production, connecting different developers, production lines and customers.

Clearly, these roles require very different sets of skills. Perhaps it is useful to imagine this reorientation as being enabled by a (re-)qualifying learning path for the

[2]Gorz would of course have used the term “alienation” instead of “abstraction”.

present worker. Staying in the inferior role is not an option. Not only is this work quite unchallenging, there will be little demand for it in the future:

> Fortune will instead favor […] those who can innovate and create new products, services, and business models. [13]

When looking at the three models as a kind of development path, however, it is possible to imagine that process workers will evolve to (re-)discover their abilities and become masters of certain skills sets that will, in turn, lead to robots and production lines that are built to their abilities and likings. From this position, it is not a huge step to become the architect of the entire factory layout, which will be in constant flux in order to connect the different type of developers, customers (acting as producers) and the production lines that need to serve these groups. This movement, in fact, has been with us for some time:

> It is sometimes said, that the mass manufacturing ended the role of the craftsman, who was replaced by heavy machines stamping out identical parts. In fact, craftsmanship moved into the engineering department, where products are designed and their means of manufacture devised. ([26], 128)

Learning the skills needed for this qualification—one may argue—will be difficult and not possible for the worker. But Digitization and its new forms of organisation has always been about enabling skills that were neglected and suppressed by the traditional hierarchy ([1], 121ff., [8], 29ff.). Thus, we can anticipate that digitally augmented learning paths will be available to anyone and may make ascending the ladder easier and more feasible [5]. The worker would ultimately behave like an "Edupunk" somebody who could create his learning path not only by using elements of traditional education but also from downloaded learning content and peer learning:

> The way I look at it, a complete personal learning plan ought to have four parts: finding a goal and the credentials or skills needed, formal study, experiential education, and building a personal learning network. ([21], 137)

This educational task will be become an important part of the workers role, and will mainly be his responsibility, if the experiences of freelancers who already operate in a less binding and more open working relationships offer any indication:

> We not only take all the risks of our job moves, we assume the task of taking care of our creativity of investing in it, and nurturing it. […] Increasingly workers have come to accept that they are completely on their own-that the traditional sources of security and entitlement no longer exist, or even matter. ([16], 99)

We can furthermore suspect that companies will develop demographic HR-strategies that will shape and influence the development path described here:

> The VW board member for human resources, said robots would fill some of the retiring baby boomers' jobs, not people. He did however insist that robots would take over the more monotonous or unergonomic tasks allowing human employees to focus on more highly skills jobs. 'We have the possibility to replace people with robots and nevertheless we can

> continue to hire the same amount of young employees. Or put the other way: we would not be able to compensate for this outflow of retirees by [hiring] young employees'. [23]

The worker—so it seems—must embrace some kind of *learnership*, the ability to be a competent author of *"[…] one's individual learning journey by leveraging the vast learning opportunities offered by personal networks and the global marketplace*" ([15], 265).

By introducing the need to model CPS according to human skills and recognizing the changing nature of the factory, we suddenly have a wide and rich array of different tasks and profiles for the human, which have somehow been obscured by the image of the process worker. By focusing on the process worker image exclusively, we may have followed a practice that recognized the factory worker as a steady and fixed "factor" of the production plant, unable to fully use his or her capacities and take any active part in the development and refinement of his or her skills. This perception—one must hope—can now be left behind, just like the old factory.

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