The cunning of instrumental reason: Changing the world with self-reproducing 3D printers.

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Abstract:

The paper investigates the relation between two approaches for transforming the world, one wedded to the development of technology and industrial revolutions, the other stressing popular mobilisation and articulation of conflict. This discussion takes foothold in a case study of a low-cost, open source 3D printer called ”Rep-rap”. The aim of the Rep-rap project, as explained by its founder in a programmatic paper titled ”Darwinian Maxism”, is to spread a self-reproducing 3D printer to the masses. It is hoped that this will undermine the market in 3D printers as well as markets in every other kind of goods that could be printed on such a machine. In short, Darwinian Marxism is a roadmap for transcending existing market society. These ideas are compared with a longer history of utopian thinking among engineers, beginning with the French revolution and leading up to the cyber-political imaginary of the 1960s counterculture.

Introduction

”Socialism was introduced into silk-weaving workshops with the mechanics of the Jacquard loom; it profoundly modified the habits, interests and material and moral circumstances of weavers” (Monfalcon, 1866: 365, my translation)1

The librarian of Lyon who thus attributed the birth of socialism to the mechanics of the Jacquard loom made his remark with strong disapproval. He was working on a chronicle over Lyon and offered his explanation to the violent uprisings by weavers that had shaken the town thirty years earlier. As he saw it, the Jacquard loom had raised the living standard of workers, thereby encouraging them to ask for even more and to become recalcitrant. What interests me with the quote is not the claim that the Jacquard loom improved the standard of living of the weavers, nor that their radicalism owed to an excess of affluence, as opposed to a deprivation of it. Both claims are questionable (Strumingher & Bolo, 1978). Of greater concern for my argument in this paper, is that the quote connects the introduction of a new technology with the birth of a political, even revolutionary, idea: that of socialism. Still more intriguing, the technology in question is the famous Jacquard loom. The operations of the loom were guided by punched cards. With this innovation the principles of software had been worked out for the first time in history. A century and a half later, punched cards were still being used to control machinery tools in heavy industry (Noble, 1986). It is the same principle of controlling the movements of a tool head with software that lies at the heart of 3D printing. As for socialism, the idea of developing a 3D printer for the masses was conceived with the aim of bringing about a radical transformation of society. Adrian Bowyer, the founder of the open source 3D printer ”Rep-rap”, offered the following analysis in a programmatic paper when he launched the project:

”So the RepRap project will allow the revolutionary ownership, by the proletariat, of the means of production. But it will do so without all that messy and dangerous revolution stuff, and even without all that messy and dangerous industrial stuff.” (Bowyer, 2004)

In the Rep-rap project, large-scale political visions and hands-on, pragmatic development work come together. The project provides a stepping-stone for reflecting over the relation between, on the one hand, industrial revolutions, and, on the other hand, social revolutions. The word ”revolution” can alternatively be read out as ”politics”. What is at stake, then, is two different understandings of how to think and do politics. One approach prescribes technological development as a means for promoting social change, the second puts faith in popular mobilisation and the articulation of conflicts. My intent is *not* to contrast the two ideas of revolution/politics in order to find one of them in fault. I need to stress this point, because social scientists like myself tend to side with the latter and be unfavourably disposed towards the former (*but cf*. Wyatt, 2008). Instead of restating the

opposition between the two, I highlight their common historical roots and inter-dependencies. There was a time when the politics of the engineer and the politics of the social reformer were not clearly separated and set against one another. As I will come back to in the paper, the parting of their ways had something to do with the rebellious weavers in Lyon. If I choose to put stress on commonalities instead of divergences, it is partly because the two ways of thinking and doing revolution/politics seem to be converging again. Geeks and engineers are forced to engage in politics in response to intellectual property laws and related enforcement regimes. Social movement activists, in return, are compelled to become acquinted with natural science and engineering in order to make sense of the social conflicts that are the order of the day (Kirkpatrick, 2004; Dunbar-Hester, 2012).

My discussion of these questions take foothold in a case study of the Rep-rap project conducted over a 2-year period. It draws on 17 interviews with core developers and other key participants in the Rep-rap project. A secondary source of information has been the texts published on discussion forums and blogs dedicated to the development project. Elsewhere I have investigated the practices of the hobby-engineers (Söderberg, 2013b). I will leave this important question to the side for now. Another concern which I have dealt with previously and which will only be mentioned in passing is the legal repercussions of distributed 3D printing (Söderberg & Daoud, 2011). In this paper, my focus is on the ideas and values animating the Rep-rap project. In the first part of the paper, I will describe the ideas behind the Rep-rap project. In the second half, I will compare those ideas with the history of utopian and political engineering thought. Towards the end of the paper I tease out some observations about the possibilities of thinking revolution/politics in an age of unbounded, instrumental reason.

A program of Darwinian Marxism

Among the machinery tools that furnish personal/desktop manufacturing, the low-cost 3D printer is the crown jewel. It was the Rep-rap project that created a low-end market in 3D printers. The principle behind the Rep-rap 3D printer is that a material (usually plastic) is melted and put down in layers to build a three-dimensional object. This offers a highly versatile manufacturing process. The potential for future improvements of the technology is vast. Concurrently, and unlike some other fabrication methods, 3D printing does not involve toxic chemicals, it does not emit dangerous fumes, nor does it require high-voltage electricity. In short, 3D printing is ideal for hobbyists working at home (Ratto & Ree, 2012). This was a key consideration when the Rep-rap project was first conceived, because the aim of the project is to decentralise industrial manufacturing processes. The aim of the hobby-engineers fit into the larger imaginary of a 'geek public' (Kelty, 2008). What makes the Rep-rap project stand out, however, is that those ideas have been elaborated into a full-fledged political program.

The ambitions of the Rep-rap project can rightly be termed 'civilizational'. The vision of the initiator, Adrian Bowyer, shared by at least some of his closest collaborators, is to disrupt established patterns of industrial production, global distribution networks, and mass consumption. In its place they envision a new regime of decentralised, peer-to-peer manufacturing. This transformation is framed within a biological and evolutionary imaginary. Everything hinges on the capability of the 3D printer to print (most of) its own parts. With such capacity, the growth curve of the machine park of 3D printers becomes self-reinforcing. That is to say, existing 3D printers can be used to build new 3D printers. The wider implication thereof was sketched out in a programmatic text by Adrian Bowyer with the subtitle 'Darwinian Marxism'. The pivotal idea in the paper is that once the 3D printer is capable of making its own parts, the machine will start to mimic a key feature of living beings: self-reproduction. The name 'Rep-rap' is an abbreviation of self-REPlicating RAPid prototyper. Tribute to biological science is paid in the names given to the official versions of the Rep-rap 3D printer: the first generation of 3D printers was called Darwin, the second Mendel, then Huxley.

The claims made on behalf of the Rep-rap project have been enthusiastically received by segments of the geek public, although others have reacted with scepticism. The latter usually take aim at some technical hurdle. For instance, only half of the parts for the 3D printer can be printed, leaving out the most complicated parts, microelectronics and motors. And even if the day comes when every single part can be printed, a human being is needed for assembling the parts. Hence, a frequently recurring objection to the Rep-rap project is that its claims about building a self-reproducing machine is hyperbolic and misleading (Perens, 2008). Bowyer had already anticipated this line of objection in his programmatic paper. He riposted with the idea of ”symbiosis”. The machine can be said to reproduce itself if we allow for a more distributed view on reproduction. The 3D printer reproduces itself in symbiosis with the user. The human being is willing to assist in the reproduction of the machine because she is rewarded with consumer goods. This is analogous to the way the wasp assists in the

reproduction of orchids in exchange for nectar. It might now sound as if Bowyer has rendered meaningless his initial claim about a machine capable of self-reproduction. But a more rewarding critique of 'Darwinian Marxism' can be developed.

The idea of ”symbiosis” has a bearing on another kind of objection, which, no doubt, springs to the mind of a historian or social scientist the moment he or she hear about a 'self-reproducing 3D printer'. To such a reader, the claim will sound uncannily similar to an old engineering fantasy: that of the fully automated factory (Turner, 2008). When the notion of ”symbiosis” is introduced, however, this objection must be qualified. The human being has been enrolled in the reproduction process of the machine, though one crucial aspect of the human is being left out, her consciousness. The wasp-orchide synergi draws exclusively on her instincts. Having said that, concious decision making resurfaces at a different level of the equation. The point with having a 'self-reproducing 3D-printer' is that the critical parts for the machine can be made on a second machine, which is to say, on the machine of a second hobbyist (Olliver, 2010-05-04). What is at stake is the 'functional autonomy' of the collective of hobbyists. I borrow the term 'functional autonomy' from the labour historian David Montgomery and I use it in the same way he did. He described worker struggles in nineteenth century industry where the workers collective often had de facto control over the production process. The collective of workers had a functional autonomy vis-à-vis the factory owner thanks to their superior familiarity with tools and practices. Montgomery showed how the transformation of existing work practices and production processes through the introduction of new technology had contributed to undermine the functional autonomy of workers (Montgomery, 1976). Its logical end-point, of course, was the fully automated factory.

In the case of the Rep-rap community, the risk of losing functional autonomy is as acutely felt as it was in nineteenth century workplaces. But the significance given to technology and automation has been diametrically reversed. Furthermore, the threat does not come from an employer, narrowly speaking, but from start-up firms and venture capital. A quick example can serve to illustrate my claim. When the second-oldest start-up firm, Makerbot Industries, was founded in 2009, the company inherited the stock of electronics which had at a previous date been entrusted to the non-profit Rep-rap Foundation. Makerbot Industries thus became an obligatory passage point for hobbyists wanting to build a Rep-rap 3D printer. At the time, Makerbot Industries was enmeshed in the Rep-rap community and avowed its commitment to the same values of openness. Still, many of the hobbyists had had misgivings about being dependent on the good-will of a single firm. It spurred a number of secondary development projects of alternative electronics, out of which some aimed for electronics designed for home production. In theory, the existence of homebrewed electronics for the 3D printer would ensure that no single firm could be in control over this critical component, and, by extension, over the Rep-rap community. In practice, to make electronics at home demands a lot of know-how and equipment, thus limiting this alternative to a few very resourceful hobbyists (Markus Hitter, 2011-09-11, Söderberg, 2013b). It is in this light that one should see the long-term goal of the Rep-rap project to make the 3D printer capable of printing conductive materials. This would be a major step towards a 3D printer capable of printing the electronic parts needed to build a second 3D printer. Objections about the technical feasibility of such a scenario can be left aside for now. The point I want to make is that automation in the Rep-rap community has taken on the opposite signification compared to what it had to the workers in the nineteenth century factory. Automation is pursued by the hobbyists with the aim of preserving the functional autonomy of the community vis-à-vis firms and venture capital.

In principle, the hobbyists welcome firms that sell derivatives of the Rep-rap 3D printer. The pragmatic attitude towards making allies with for-profit ventures coalesces with broader trends in political thinking. Unlike most social movements, however, the Rep-rap project adopts pragmatism while maintaining a long-term vision about transcending the market economy. Paradoxically, the undoing of markets and firms will come about through a co-existence with the same. This belief lies behind the open invitation that the Rep-rap project sends out to businesses. The argument is constructed around the idea of evolution, although here applied to the self-propagation and 'natural selection' of 3D printers. This application of evolutionary laws to the field of technology rests on a presupposition about rational user-individuals acting on consumer impulses, luring them into a symbiosis with the self-reproducing machine. The origin of this assumption is easy enough to identify, neo-classical economic theory. But the actions of the user-individual will not aggregate spontaneously to make up a new market. Quite to the contrary, when every home has been furnished with an ubiquous manufacturing process unit (i.e. a 3D printer), then most market exchanges will be rendered superfluous. The centrality of this idea for the hobbyists is suggested by the by-line of the Rep-rap project: ”wealth-without-money”. Some more clues are given by Ed Sells, formerly a PhD candidate working in Adrian Bowyer's laboratory, second person to have joined the Rep-rap project, and chief architect of the Mendel generation of the 3D printer. Pondering over the scenario

that HP or some other multinational company will try to outmanouver the Rep-rap project, he develops the following counter-scenario:

”I think that Adrian has hit on a mechanism which is so unbelievable powerful. When you got something making itself, it is scary from the point of view of HP […] Self-reproduction wins over anything else, over any linear production. Rep-rap exposes the fact that if you got a 3D-printer, it can make itself. So HP will go: 'well, we are not going to make any money here'. And the fact that Adrian has made it open source from day one means that there is nothing to stop people designing around someone [i.e. HP] coming in. I dont think you can stop Rep-rap except if you get on safe distance and nukes it.” (Sells, 2010-05-07)

The quote alludes to two factors believed to give the Rep-rap community an edge over commercial vendors. The first is the possibility to design around any chokepoint imposed by a firm. The case with the Makerbot Industries and the home-built electronics examplifies this claim. The second is the speed by which the 3D printer will spread and develop. This point needs to be elaborated a bit further. While components for a Rep-rap machine can be printed on either another Rep-rap machine or a commercial 3D printer, this does not work the other way around. The firms have no interest in designing their 3D printers in such a way that the product could alternatively be made on a Rep-rap machine. To underline this point, the commercial 3D printers are called ”Rep-straps” by the hobby-engineers. Rep-strap is the name given to machines which can be used to build (or ”bootstrap”) Rep-rap machines, but cannot make copies of themselves. This asymmetry is believed to give the Rep-rap 3D printer an advantage over commercial derivatives. As the market for commercial Rep-straps grows, the machine park of Rep-rap printers (and with that, the Rep-rap community) grows with it. Potentially, at least, the community will grow faster than the market, since the Rep-rap project benefits from the above mentioned one-directionality in the diffusion of 3D printers (Bowyer, 2009-11-24).

In the paper by Adrian Bowyer, a thought experiment is proposed where the output of a self-printing 3D printer is compared with an injection molding machine. The latter technique is an industrial standard for mass production of consumer goods. In the long run, and provided that the question of exhaustible resources is bracketed, self-replication will numerically overtake mass production. This will happen by the same force as exponential growth outdoes linear growth. On paper, at least, there now exists an answer to the question which has shipwreck many socialist and anarchist dreams: How can an alternative economy be designed where the goods are delivered as efficiently as in the current, centralised and industrialised market economy? More important than the brute, numerical advantage is the superior dynamics ascribed to an open and decentralised innovation process. This idea originates in open source-guru Eric Raymond's iconic catch-phrase: 'add more eyeballs and all bugs are shallow'. In other words, innovation will accelerate faster the more people get involved in the process of discovery. This ensures that the greatest diversity of perspectives is at hand, thereby increasing the chances of finding a novel solution to an old problem. Starting with this observation, Raymond inferred that an open and decentralised development process will win out over a closed and/or centralised development process (Raymond, 1998). The hobby-engineers in the Rep-rap project have integrated this idea within the narrative about evolutionary biology. Diversity is a prerequisite for natural selection, and natural selection ensures that the best technical option will prevail over faulty designs. When the design is closed behind intellectual property claims, diversity is stifled and the engineering project runs into an evolutionary dead-end (Prusa, 2011-09-19).

Not everyone in the Rep-rap project, perhaps not even the majority, subscribes to the ideas about biological evolution sketched out above, though the most influential and active developers do. Likewise, not everyone cares about the stated goal of contributing to large-scale, economic and social change. Just as with other hobby-engineering projects, the joy of tinkering with technology might be the most enticing reason for people to be involved (Kleif & Faulkner, 2003). Other motives are the possibility of getting a 3D printer at a cut-rate price, and, increasingly, the growing business opportunities within a booming consumer market for 3D printers. However, the possibility of harboring such diverging viewpoints under one and the same roof is part of what makes the call for diversity so appealing. Diversity is not just seen as a principle leading to superior technical sollutions. It embodies the ethical and political values which constitute the raison d'être of the Rep-rap project. The value of diversity is set against the current mode of centralised mass production. Furthermore, on a day-to-day basis, appeals to diversity are part and parcel of project management. Conflicts between members of the core team over design choices and long-term strategies are commonplace. Under the sign of diversity, developers are encouraged to wander off to design-and-let-design. The assumption is that natural selection will sort out the wrong from the right (Prusa, 2011-09-19 ; Sells, 2010-05-07). In fact, the vindication of ”diversity” does roughly the same work for the hobbyists as the notion of ”pluralism” does for the alter-globalisation movement. Both words

signify the antidote of party lines, ossified ideologies, and secterianism.

Just as with pluralism and tolerance, the value of ”diversity” has an Other. Paraphrasing Herbert Marcuse's memorable expression, this Other can be named ”repressive diversity” (Marcuse, 1969). From early on, objections were made about the second name in the phrase ”Darwinian Marxism”. The name of Karl Marx was perceived to be in conflict with the value of diversity. Concern was expressed on the discussion forum that newcomers might feel excluded by it. The paper on Darwinian Marxism and references to the wealth-without-money philosophy, initially fronted on the website and in communications with the press, were pushed to the back. The same concern for diversity is reflected in the general lack of enforcement of the publicly stated committment to free sharing of information. When someone on the discussion forum tries to name-and-shame a firm for being out-of-line with the open license, that person can expext to be reprimanded in turn for his lack of appreciation of diversity. All the while, tensions are growing in the Rep-rap community in proportion to the growth of a consumer market in 3D printers. The pattern is known from other social movements that have tried to gain a leverage in society by making alliances with for-profit ventures. Success is often bought at the price of having the original goals diverted (Hess, 2005). In the Rep-rap project, a turning point came in autumn 2012 when Makerbot Industries announced that it no longer allowed the community to access the design of its latest products. Indignation ran wild on the Internet, and some called for Adrian Bowyer to intervene. In part defending himself against the accusation that he was too lax in enforcing the open license policy, Bowyen responded as follows:

”When it comes to the success or failure of RepRap, moral beliefs, legal constraints and the flow of money are almost completely irrelevant. It is the evolutionary game theory that matters.” (Bowyer, September 21, 2012, Makerbot blog)

Differently put, the actions and intents of the hobby-engineers are irrelevant to the unfolding of an impersonal, cumulative causation, abiding only to the laws of evolution, but which nevertheless is moving towards the social transformation longed for by the hobbyists. At first, this might sound like a convenient way for the engineers to excuse any opportunistic venture they might choose to embark on, for instance, Bowyer's investment in Makerbot Industries shares, which he confesses to in the same message. It is easy to mount objections to the reasoning above, but such a critique may obcure something equally interesting, why the argument is compelling to so many. Adrian Bowyer's response was copied and favourably cited on numerous other forums. It is not only the actions of the hobby-engineers that are made irrelevant by evolutionary game-theory, but so are counter-actions by vested interests. Given that the playing field is heavily tilted in favour of the latter, exemplified by law and money in the quote above, the appeal to an extra-social, higher instance becomes very attractive (Söderberg, 2013a). It follows that grand-scale social change can be had without a direct confrontation with the powers-that-be, which is to say, without a messy and dangerous revolution. Thus stated, it becomes clear that the hobby-engineers have stumbled over a recipe for social change that has waxed and waned in leftist thinking over the years. Namely, the idea that the System can be changed through a withdrawal from the same. A first wave of withdrawal was attempted already by the followers of Fourier, Cabet and Saint-Simon in the aftermath of the miscarried French revolution (Corcoran, 1986). In *Eighteenth brumaire of Louis Napoleon*, Karl Marx succinctly described those experiments as attempts to go ”behind the back of society”. Marx considered this proposition to be absurd because it was society, or, to be more precise, social relations, that acted behind the backs of individuals. Darwinian Marxism is a program for rigging the laws of evolution in order to smuggle social change behind the backs of society and individuals alike. It seeks to transcend capitalism through the 'cunning of instrumental reason'.

Historical overview of engineering ideology

The ideas outlined above are fairly consistent with the orthodox Marxism associated with the Second International. It laid down that human emancipation would march hand in hand with the gradual advancement of science and technology. Increases in social wealth flowing from ever-more powerful forces of production provided an assurance in the last instance that capitalism would eventually be transcended. What is the dream of having a 3D printer, capable of printing almost everything including a copy of itself, if not a manifestation of the forces of production at its apex? The extent to which this vision conforms with Karl Marx's thinking is an object of intense, philological debate. According to one position, the scientism characteristic of Second International Marxism originated in Friedrich Engels' own texts and/or in his editing of Marx's manuscripts post-mortem (Levine, 1973, *but cf.* Gouldner, 1980). Intriguingly, Engels too turned to nature in search for laws (of dialectics) which would strengthen his case that capitalism was a transient phase in human history. Perhaps then 'Darwinian Engelism' would have been a more appropriate heading for the political program of the Rep-rap project (Engels, 1987).

That said, faith in the emancipatory potential of science and technology was not a trait specific to late nineteenth and early twentieth century Marxism. Those ideas were a common heritage of the Enlightenment, and its firstborn children were the engineers. Another idea vindicated in this milieu was the elevation of nature as a metaphor for thinking the possibility of social change. In the eighteenth century, as the epistemological framework of the Enlightenment developed, French engineers begun to discern dynamic forces in nature. The dynamism was taken as a model for their concept of technical efficiency. This interpretation was charged with political undertones, because nature thus understood was contrasted with the blockages and inefficiencies of the feudal order (Jakobsen, et al. 1998; Picon, 2009). Henri de Saint-Simon excelled in this line of thinking. Initially an enthusiastic supporter of the French revolution, he became dismayed by the bloodshed that it had unleashed. He greeted the embryonic industrialisation of France as a force that could complete the task that the political revolution had left unfinished, that is to say, to eradicate ancien régime. Against the feudal order he marshalled the productive members of society, what he called the ”industrialists”. Under this label he grouped bankers, patrons, artisans, craftsmen and workers, without registering the emerging lines of conflict between these different groups (Saint-Simon, 2012; Musso, 2010).

This ambiguity was inherited by Saint-Simons' followers, where one wing courtised bankers and factory owners, while the other wing sympathised with the growing mass of pauperised workers. In-fighting and the eventual suppression of the socialist wing of the Saint-Simonians coincided with the first uprising of the weavers in Lyon in 1831 (Musso, 1999: 111f). The Saint-Simonians had hurried to Lyon to profess their utopian ideas to the workers, and, as a consequence, was singled out by state authorities as responsible for the uprising (Rude, 2007; Musso, 2010). The historian Pierre Musso has suggested that the state repression that followed encouraged the remaining Saint-Simonians to change their rhetoric and style of thinking. The role of social struggle was played down in the transformation they professed. Social change would instead come about through the development of communication networks, chiefly railways and channel. This proposition resonated with the strong presence of engineers educated at École Polytechnique (Musso, 1999). Accordingly, the articulation of conflict was opposed to cooperation for the common good. Decision-making should be entrusted to those who were most knowledgeable and impartial, by which was meant – the engineers (Savigear, 1971).

The split of the Saint-Simonians, catalysed by the uprising of Lyon textile workers, could be assigned as the historical moment when the two approaches to revolution/politics parted ways. One path stressing political mobilisation and articulation of conflict as a means of changing the world, the other path playing down overt conflicts while smuggling in social change through laws of nature, behind society's back as it were. In 'geek publics', this tension is sometimes testified in the crystallization of a ”hacktivist” and a ”techie” camp, as exemplified in the old stand-off between Free Software Movement and Open Source Initiative (Berry, 2004), in the differentiation between hacklabs and hackerspaces (Maxigas, 2012), and, indeed, in the various fractions found in the Rep-rap project. What is crucial to note here is that this tension does not simply play out between two opposing camps, but is reproduced within the discourse of respective camp. After all, the techie who stresses bare, incontestable facts over loose opinions and debateable values is drawing on a political, even a hegemonical, rhetoric (Gillespie, 2006). Reversely, when the political assertions of the hacktivist are to be translated into something substantial, the question of efficiency must be addressed.

The inclination among engineers to anchor their ethical and political claims in nature was given a new impetus with the breakthrough of evolutionary biology in the second half of the nineteenth century. In countries where the ancien régime lingered on, for instance in Germany, the publication of On the origin of the species was greeted by the bourgeoisie as an ally in their struggle against the aristocracy. Later on, when the central conflict lines had shifted, and the bourgeoisie confronted an ascending working class, the meanings invested in ”nature” changed as well. Natural selection was now called upon to prove that market competition was a mere reflection of the eternal order of nature (Pannekoek, 1912). The name to mention here, of course, is Herbert Spencer. His writings on social Darwinism became immensely popular. Spencer's influence on his contemporaries should be stressed, because today his name evokes little but hostility or disinterest. Perhaps it is no accident that Spencer was an engineer by training (Sharlin, 1976). Edwin Layton goes as far as to argue that social Darwinism was the founding ideology when the engineering profession constituted itself in late nineteenth century. Although the ideas of the engineers were never developed into a single, coherent doctrine, certain ideas recurred over and over. Key was the assumption that nature and society are governed by laws which are accessible to human knowledge. Those laws were held to be immutable and incontestable. But this was not understood by the engineers as a limitation on their freedom to act. On the contrary, it was through the manipulation of nature's laws that the engineers could exercise influence over society. Layton underlines that the popularity of these ideas surged at a time when the

subordination of the engineering profession under corporate bureaucratic hierarchy was being consolidated in America. Having the feeling of being under threat, social Darwinism was called upon to assure the professional values and identity of the engineers (Layton, 1986, p.55).

Layton goes on to argue that the same ideology was extended and codified with Taylorism half a century later. The scientific doctrine of Frederick Taylor was flagged as a means for improving effectivity in industry. It was at the same time a program for solving ethical questions, marked by a context of intense class conflicts. Taylor and his followers believed that they had discovered immutable laws about management which had the same force as nature's laws. They imagined the engineer to be an impartial judge and interpreter of those laws. The engineer was thus lifted above the messy world of politics. In particular, he was imagined to stand above the conflict between workers and managers. It was the anti-political outlook of the engineer which made him suited as an arbiter in politics. This worldview provided the germ of what would a few decades later develop into the notion of an end to class conflicts and ideological strife (Maier, 1970).

The name of Frederick Taylor evokes images of satanic mills and factory despotism. Just as with the deterministic laws of nature, things looked differently from the vantagepoint of the engineers. Coupled with Taylor's promise of increasing industrial production was a bid for enlarging the autonomy of the engineering profession. This would come at the expense of blue-collar workers, needless to say, but it would also restrict the autocratic, unscientific rule of managers (Zussman, 1985, p.6; Layton, 1986, p.139). Suggestive is Taylor's complaint about managers ”who merely cracks his whip over the heads of his workmen and attempts to drive them into harder work for low pay” (Taylor, 1911, p.58). There was enough of ambiguity in Taylor's thinking to allow some of his disciples to put an anti-corporate spin on scientific management. This points us to a split in the conception of rationality that runs from Saint-Simon to the Rep-rap hobbyists. Rationality defined on technical grounds and oriented towards the production of social goods, the engineering position, comes up against pecuniary rationality defended by economists, managers and owners. The most systematic elaboration of this cleavage is found in the essays that make up Thorstein Veblen's The engineers and the price system. Although himself not an engineer, Veblen was inspired by ideas that he had encountered among engineers, and he influenced some of them in turn (Stabile, 1986; Knoedler & Mayhew, 1999). Intriguingly, he too mobilised Darwin and the idea of evolution against economics and the economic science of the day. Free markets had become obsolete in modern society and was now holding back progress, he charged. In an industrial society, the engineers were the ones best qualified to take informed decisions about the future of mankind. Writing shortly after the revolution in Russia, he famously called for a 'Soviet of technicians' in America (Murphree, 1959; Veblen, 2001, p.83). Veblen had a decisive influence on the Technocracy movement that surged in the wake of the Great Depression. They professed the imminent downfall of the price system and advocated emergency preparations to accomodate a more rational society based on the principles of science (Adair, 1967). The legacy of the Technocracy movement runs strong in hobby-engineering communities today (cf. Wallace, 2007).

If the agitation of Thorstein Veblen failed to enflame the larger collective of engineers, it can probably be put down to that their occupational standing were closely tied up with that of the industry and the business community. In their practices, the engineers had become attuned to efficiency as the purpose of their professional endeavors. Efficiency and functionality were facts of life against which there could be no quarrel. Thus they were at the mercy of a given definition of efficiency. After all, the supreme test of the soundness of an engineering solution was the market (Zussman, 1985, p.121). The internalisation of the goals of the business community begun already with the first day of training to become an engineer. The engineering schools created in the nineteenth century in America were quickly subsumed under the influence of local business communities. For the historian David Noble, the education of engineers was the crux in ensuring the reproduction of engineering subjectivity. The potentially disruptive practices of the engineers could thus be channelled towards entrenching existing relations of domination and exploitation (Noble, 1977). The engineering professions made attempts to assert their autonomy vis-à-vis the business community, for instance, in the struggle for control over the engineering associations in the US in the nineteenth and early twentieth century. Ultimately, however, the independence of the profession was undermined by the revolving doors between engineering jobs and the upper echelons of management. Edwin Layton concludes his study of engineering ideology with the observation that it was not free market forces that angered the engineers the most. What they were truly wexed about was bureaucracy. Once more, one can trace a lineage going all the way back to Saint-Simon. He too opposed state bureaucracy, which he associated with the vested interests of ancien régime. Improductive members of society, by which he meant the nobility, the clergy and the military, were exempted by state buraucracy from contributing to the overall advancement of mankind (Saint Simon, 2012).

Engineering ideology meets cyber-politics

The Rep-rap project has grown out of, and, subsequently, recruits many of its followers from, mechanical engineering departments. Concurrently, the values and methodologies behind the development project relies heavily on software engineering, especially in its open and ”outsider” incarnation. In the Rep-rap project, the emergent field of computer programming is reconnected to more a classical engineerging tradition. I will limit my discussion about the history of software engineering to highlight a few continuities which are reflected in the Rep-rap community, especially as regards the anti-bureaucratic thrust. The influence of the 1960s counter-culture on the then nascent computer profession has been explored in many earlier works and need not to be recited again (Markoff, 2005; Flichy, 2007). A couple media scholars have stressed how this strain of utopianism espoused free marketeering in a joint opposition to hierarchies and bureaucracy. Alan Liu disapprovingly calls this phenomenon ”cyberpolitics”. He argues that the detournement of cyberpolitics into a form of high-tech libertarianism was inscribed from its inception. The main achievement of scientific management was not the subjugation of blue-collar workers under factory despotism. It was the creation of a new strata of white-collar workers with a persona perfectly modelled after the dogmas of scientific management. This product of Taylorism merged with its radical Other, countercultural ”bad attitude”. Thus was created the strange amalgam which is cyberpolitics (Liu, 2004). While finding Liu's argument compelling, I ask myself if cyberpolitics is more culpable than any other of the political detournements coming out of 1968. For instance, Nancy Fraser has made similar observations in relation to second wave feminism. The ideas espoused by the feminists of this generation were from the outset susceptible to being recuperated by an ascending neoliberal world order (Fraser, 2009). Be that as it may, I readily acknowledge that the centrality of communication networks in late capitalism bestows a heightened importance to the cyberpolitical imagination. The software engineer has become the harbinger of the dreams of 1968 in an inverted, nightmarish form. Accordingly, opposition to bureaucracy translates into an attack on those institutions which guarantees stable employment conditions. The anti-authoritarian penchant of the counter-culture is gratified when the challenge is mounted against allegedly undemocratic experts and liberal professions. Employment security shelters these professions from being exposed to the ”democratic” test of market demand (Turner, 2006; Barbrook, 2007).

Removing the demand for the labour of others was always part of the job description of an engineer. In the haydays of the mechanical/industrial engineer, however, this task was undertaken with a word of regret or apology. Perhaps it was said that new jobs would be created elsewhere in the economy or that overall wealth would grow thanks to labour-saving machinery (Bix, 2000). Not so with the cyberpolitical avant-guarde where the attack on employment security is carried out with a messianic zeal. The filesharing debate is a case in point. Although the music corporations are the the designated target of politicised filesharing activists, there are consequences for professional musicians too. The busking artist is often heralded as a proof of the fact that money can be made on musik without contracts and legal protections. What impact filesharing has had on the market for music, and, subsequently, musicians, is a lengthy topic that I cannot discuss here (Oberholzer‐Gee & Strumpf , 2007; Anderson, 2011). What I want to suggest is that the employment situation for musicians is indicative of where the job market is heading for many other professions. A case in point is industrial designers, who have already begun to discuss among themselves what will remain of their profession once a consumer market for 3D printers takes off (Atkinson, 2010). To the enthusiasts of 3D-printing, the same outcome is anticipated as a democratisation of design, a field soon to be emancipated from ”experts”. When I asked Adrian Bowyer if the realisation of the goals of the Rep-rap project would not result in a massive, downward pressure on salaries, he concurred. That must not be such a terrible thing, he added, since the people affected would not have to buy so many things when they have a 3D printer in their home (Bowyer, 2009-11-24).

Adrian Bowyer's answer would be anathema for an union organiser. Still, the radicalism of his position must be acknowledged. The target of the Rep-rap project is set higher than a mere redistribution of wealth in society. Its goal is to abolish commodified labour by creating wealth-without-wages. Of course, everything hinges on that atoms too, and not just labour, are set free (”free” as in ”gratis”). (Söderberg & Daoud, 2012). It must also be granted to the hobby-engineers that they have not exempted themselves from the forces which they are partly responsible for unleashing. Indeed, their collective existence as a community of hobbyists is presupposed by the ongoing crisis of the engineering profession. As a former dean at MIT, the historian Rosalind Williams is well situated for reflecting over this crisis. From the ever-more evanescent engineering curriculum taught at MIT, she sees a loss of identity of the profession as a whole. One reason is the disappearance of the institutional settings within which lifelong engineering careers used to unfold. Granted, precarious labour demand is a condition that the students at MIT share with many other classes of workers. The engineering students distinguish themselves,

however, in having so fully internalised this condition of working life. William is concerned that the entrepreneurial outlook has erroded the public commitments which were part and parcel of the old identity of the engineering profession (Williams, 2003).

The crisis of the identity of engineers is reminiscent of the prognoses made in the 1960s and 1970s about a proletarisation of the ”middle levels”. It was then predicted that the engineers would follow in the footsteps of craft workers. As their ranks swell, engineering jobs would be routinised, they would experience a decline in salaries and status, and the level of unemployment would climb (Holbrook- Jones, 1982; Zussman, 1985; Braverman, 1999). Evidence thereof is not lacking. If I hesitate to subscribe to the proletarisation-thesis, it is because the engineers are likely to be doing a lot better than most other workers. In the same brushstroke as labour markets are undercut by technological change, the demand for technical expertise is renewed. It is noteworthy, though, that there are now trained engineers in excess of what the industry can absorb, out of which a trinkle spend their surplus time and energy on community-centred projects, for instance, developing an open source 3D-printer. And a minority of them does so while vindicating the public commitments championed by an earlier generation of engineers.

In the paragraphs above, I have argued that there are strong thematic continuities in engineering thought. Those ideas can be mobilised against the irrationality of the price mechanism, or they can be flown as a banner of free marketeering. The historians of technology discussed above attributed this ambiguity to the undecidedness of the class position of the engineer. Like the blue-collar worker, the engineer is subjugated to the dicipline of industrial organization, like the manager, he/she exercises discretion and authority over others. While this observation remains true, the significance of engineering thought is modified by the institutional settings that have been thoroughly transformed, not to say liquefied. Engineering ideology was formulated at a time when the profession was asserting itself vis-à-vis workers and managers. Nowadays, the avant-guarde position among engineers is found at the frontline of deprofessionalisation. Nothing illustrates this better than the figure of the hacker, from which the Rep-rap project borrows extensively. By definition, the hacker is an outsider vis-à-vis institutions and professions. The hacker, having ”set free” software development from the constraints of corporate hierarchies, is himself set free from contractual employment. What the hacker has done to himself and to software development, the hobby-engineers strive to do for the design and manufacturing of all kinds of physical goods.

Conclusion

The article started out by noticing that there are two related but partly opposed ideas about revolution, and, by extension, politics. One idea prescribes social change through the development of new technology, thus shortcircuiting a clash between opposing interests, the other idea stresses popular mobilisation and articulation of conflict, possibly culminating in a violent uprising. Truth to be told, the track record is not particularly promising for any of them. As for the technology-induced revolution, David Noble identified the key question to be asked more than 30 years ago: How can it be that everything seems to change all the time while nothing essential moves? He looked for an answer in the engineering schools that reproduced a certain engineering subjectivity. Assuming that Noble was right, what is one to make of the current deprofessionalisation of engineering practices, testified in the existence of an ever-expanding community of *hobby* engineers? The same observation holds for education. The hacker personifies a learning process that has escaped established engineering curriculums and corresponding educational institutions. As the Mentor put it in his famous manifesto from 1986, the hacker rejects the pre-chewed chunks of knowledge spoon-fed to him by the teachers.

The Rep-rap project sets out to provide one piece of the puzzle in a larger infrastructure for peer-to-peer manufacturing. With such an infrastructure in place, engineers could bypass the centralisation imposed by fixed capital and mass production. It is a roadmap for an ”exodus” of engineering practices from wage labour relations and (which is the same thing) commodity production. The role assigned to ”self-reproduction” in this larger scheme of things, although framed in an imaginary of evolutionary laws and technical determinism, testifies to the very opposite, the importance of design choices. The kind of 3D-printer that can reproduce itself (in symbiosis with human beings) has been designed to ensure the functional autonomy of the community vis-à-vis firms and venture capital. The opposite scenario unfolds if the community relies on a Rep-Strap, that is to say, on a 3D printer where critical parts can only be made with large capital investments. From that moment onwards, the need arises for a return on investment, which prompts rationalisation, giving rise to hierarchy, employees, and so on. Perhaps then the open source Rep-rap 3D-printer, when combined with other tools in a larger peer-to-peer

infrastructure, meets the criteria laid down by Herbert Marcuse, as to what would constitute a new technology:

”The technological transformation is at the same time political transformation, but the political change would turn into qualitative social change only to the degree to which it would alter the direction of technical progress – that is, develop a new technology.” (Marcuse, 1964, p.227).

The Rep-rap project are enmeshed in day-to-day, hands-on development work, but do so with an eye on the goal of transcending capitalism. In contrast, when social movements begun to endorse pragmatism and micropolitics post-1989, they came to terms with the present as an unsurpassable horizon for politics. Students at engineering departments where insulated from post-modernist self-doubt, and never stopped dreaming about a radically better tomorrow. The meta-narrative of the Information Age harboured those transcendent dreams, all the better since it was made up by disillusioned Trotskists in the first place (Barbrook, 2007; Söderberg, 2013a). In some respects, it is the engineers and not the social movement activists that have preserved the flame of the *lumières*. This might prove important, since, from environmental science to computer hacking, a growing influence of engineering cultures and geek publics on traditional social movements can be detected.

Activists issued from social movements and social scientists have something to offer to geek publics in return. Social theory is still required to articulate conflicts unfolding behind the back of individuals. State and corporate bureaucracies are clearly visible targets for hackers and hobby-engineers. Those institutions which seemingly arise spontaneously out of the aggregation of individual choices, i.e. markets, are not always so. At times, engineers have denounced the price system as contrary to a rational and scientific organisation of society. At other times, price is just a fact of nature, from which evolutionary laws can be deducted, and the efficiency of a technical solution measured. If the latter standpoint wins out, the market disappears from view, and all the fervour is directed against bureaucracies, state regulation and, with that, employment security. The risk is then overbearing that the dream about wealth-without-money will be realised in its nightmarish form, as wealth-without-wages.

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