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Networks in Assembly: Investigating Social Factors in Robotic Automation

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Abstract

Automation will be one of the shaping influences of the coming decades. The increased application of robots in assembly will undoubtedly change these work environments. However, studies which attempt to predict the effect on the labour market resulting from the automation of work processes and the replacement of jobs suffer from overly simplistic dichotomy between routine and non-routine tasks. In contrast, research at the micro-level of the shop floor has shown that even routine tasks draw heavily on informal knowledge and experience. This paper reviews the concepts which describe these work processes and the necessary forms of knowledge and experience. I then argue that the literature on social networks in organisations can provide useful conceptual and methodical tools to investigate how these kinds of knowledge and experience are transferred between workers. Social network research therefore can serve as a way to shed light on the social factors in robotic automation. The paper concludes with the opportunities which the application of network analysis to assembly can provide for social network research itself.

Key words: Automation, Robotics, Work processes, Social networks

JEL codes: L2, J5, O33

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1 Introduction

Among the manifold changes which are assumed to shape the 21st century, the rise of robotic automatisations stands out in its already wide ranging implementation and the fears and dystopian forecasts over alleged negative consequences. This rise of robotic automatisations can be illustrated along two lines: First, the statistics provide a strong picture of steadily increasing application of robots. 2015 saw a further annual increase by 15 percent to 253,748 units in global industrial robot sales (IFR 2016a, p. 11) while the number of service robots sold increased by 25 percent to 41,060 units (IFR 2016b, p. 1). However, this development is limited geographically and by industry: Three quarters of the sold industrial robots were installed in only five countries¹ (IFR 2016a, p. 12). The difference in sold robots between industry and services already indicates a concentration of robotic automatisations. In addition and although the growth slowed down in 2015, the automotive sector dominates robotic automatisations within the production sector (IFR 2016a, p. 14; Pfeiffer 2016, p. 2).² Second, these developments are accompanied by the exhaustive media coverage and the repeated feature of this topic within policy circles. Prominent newspaper like The Guardian or The New York Times report not just on new successful and unsuccessful applications, political and ethical discussions on artificial intelligence and the diffusion of robots into everyday life but also extensively on the economic impact of increasing application of robots in production and services (e.g. The Guardian 2014; The New York Times 2017). A 2016 report by the World Economic Forum can serve as an example of the discussion within policy circles. It discusses robotics among the major drivers of the so-called “Fourth Industrial Revolution” (WEF 2016, p. 7). However, the report states that robotics probably will only gain wider impact in the coming years (ibid., p. 10).³ In Germany, the Labour Ministry conducted a stakeholder consultation on future changes in work environments which resulted in a white paper published in 2016 (see Bundesministerium für Arbeit und Soziales 2016). These examples illustrate not only the emerging trend of robotic automatisations within broader developments of digitalisation and the “Fourth Industrial Revolution” but also the discussions over consequences which will follow from the upcoming changes.

This situation calls for scientific assessment. Among the variety of forecasts and assessments, the contribution by Frey and Osborne (2013, 2017) received plentiful attention. In their study, they examine the extent of possible automatisations in the US economy based on engineering experts’ opinions. They find that 47 percent of total US employment is at risk of automatisations (Frey and Osborne 2013, p. 48). However, their analysis starts on the level of tasks which they then aggregate to jobs at risk (Pfeiffer 2016, p. 2; Bundesministerium für Arbeit und Soziales 2016, p. 47; Bonin,

¹ These countries are in order of market size China, the Republic of Korea, Japan, the United States and Germany.

² It should nevertheless be noted that the metal and machinery as well as the electronics industry drove the growth of robot installations in 2015 (IFR 2016a, p. 14).

³ From a different perspective, Pfeiffer and Suphan (2015, p. 4) remark that “‘Industry 4.0’ is more discourse than reality”.

Gregory, and Zierahn 2015, p. 5).⁴ The adaption of the framework in the German context by Bonin, Gregory, and Zierahn (2015, p. 14) integrates this critique and estimates the share of jobs at risk at 12 percent in Germany and 9 percent in the US.

In spite of these improvements of the framework, Pfeiffer (2016) points to a more fundamental problem: Most of the studies misjudge assembly work as routine work within a routine-non-routine framework which shaped labour market research over the last decade (ibid., p. 2). This general remark is also partially discussed in the aforementioned media coverage (see Spiegel Online 2016; Zeit Online 2017). While Pfeiffer notes that this level of abstraction can be legitimised because these kinds of macro studies are not interested in processes within production plants, she stresses that knowledge about processes on the shop floor is limited (Pfeiffer 2016, p. 2). I pick up this critique and extend the insight by the literature on social networks in organisation. Based on the study by Pfeiffer and the contribution by others like Moniz and Krings (2016), I will argue in this essay that the extensive literature on networks in organizations can contribute a useful tool to investigate social processes on the shop floor. Especially informal networks have been shown to contribute greatly to the diffusion of knowledge (for example Cross, Parker, and Borgatti 2002) and the success or failure of change processes (for example McGrath and Krackhardt 2003). These aspects - knowledge, its diffusion and social factors during implementation phases - are of crucial importance for the future changes in production (cf. Pfeiffer 2016, pp. 4-5; Moniz and Krings 2016, p. 16). Similarly to Pfeiffer, Moniz and Krings (2016, p. 11) remark that the perspective of operators is usually missing in the development process of robotics applications. Moniz and Krings also call for an integration of social perspectives and perspectives of work organization. Both studies point to fruitful topics for further research on the micro level to address the apparent need for scientific assessment.

The following section will review Pfeiffer's approach and her empirical results. Subsequently, I will introduce relevant parts of the social networks in organisations literature which can contribute helpful perspectives on the issues problematised by Pfeiffer as well as Moniz and Krings. This third section then will also attempt to outline connection points between Pfeiffer's framework and the social network literature. I conclude with the remark that - in line of Pfeiffer's argument that assembly work is misjudged - research on networks in organisations has neglected crucial industries and parts of organisations, possibly on the ground that it also incorrectly viewed assembly work as pure routine work.

⁴ It should also be noted that the popularity of Frey and Osborne's (2013, 2017) study led to oversimplified receptions (Pfeiffer and Suphan 2015, p. 7).

2 Pfeiffer (2016): Humans in Assembly

As mentioned, Pfeiffer's (2016) starting point is the common characterisation of work in assembly as repetitive and routine. She argues that this perception not only leads to an overestimation of the degree by which this work can be substituted by robots and other means of highly automated production technologies⁵. In addition, perceiving assembly work as routinised usually results in the assessment that the technological change of robotic automatisisation will lead to a polarisation of the work force in a highly qualified engineering and management staff and low skilled employees tasked with actions which require only a minimum qualification. This is related to as the skill-biased technological change (SBTC) hypothesis which states a positive linear relationship between the change in labour demand and skill level induced by technological change. A more complex derivative of the SBTC hypothesis is the routine-biased technical change (RBTC) or task-biased technical change hypothesis which includes the dimension of replaceable routine tasks at a certain skill level. This leads to the assertion that technological change (which equals increased automatisisation) leads to higher demand of low and high skilled workers while workers with medium skill levels see their high routine jobs diminishing (for a more extensive discussion see Eurofound 2014, pp. 37-41). The crucial aspect is that these hypotheses do feature neither empirical evidence nor clearly stated assumptions "why routine tasks should be more frequent in middle-skilled jobs" (ibid., p. 38). Instead, the reality of the production plants investigated by Pfeiffer includes a huge majority of skilled workers who need to intervene in the allegedly smooth automated production process up to 20 to 30 times per shift (i.e. they have non-routine medium skill tasks) (Pfeiffer 2016, p. 3). Two consequences emerge from Pfeiffer's assessment that most studies empirically incorrectly describe assembly work: First, a proper conceptual apparatus is needed to theoretically describe the work processes and the humans involved in production. Second, assembly work needs to be reassessed with this conceptual toolkit. This paragraph therefore follows this order in line with Pfeiffer's article.

The distinction between routine and non-routine work is not new and was applied frequently in research on the effects of technological change on labour over the last decade. Autor, Levy, and Murnane (2003, p. 1280) distinguish in their study on the effects of computerisation between tasks that can be accomplished by following exhaustive explicit rules (routine tasks) and problem solving and complex communication tasks (non-routine tasks). Despite the centrality of the concept, it is usually ill-defined (Pfeiffer 2016, p. 4). To close this conceptual gap, Pfeiffer introduces two interrelated concepts: subjectifying work action and living labouring capacity (concerning subjectifying work action, see also Böhle 2013). The first, subjectifying work action, covers the area of skills often otherwise related to as tacit knowledge. The concept is best illustrated in contrast

⁵ While the term "robot" gains ever wider application (Pfeiffer 2016, p. 1), I refer to industrial robots if not stated otherwise (see IFR 2016a, p. 25).

to the common concept of objectifying work action which guides the assertion of routine. According to this view on work performance, we work by perceiving data, processing them to come up with a rational sequence of actions to achieve an end and finally performing these actions. In contrast, subjectifying work action is a process based on informal and tacit (i.e. not available in explicit form) experience that informs a work process marked by a dialectic and exploratory relation to the means (Pfeiffer 2016, p. 6).

This contrast is not supposed to imply that humans never follow or never should follow the objectifying script. The juxtaposition, however, does imply that both kinds of work action are of equal importance for the work process and their application is a question of the task at hand. It also implies that it is an empirical question whether or to which extent a certain task or a certain job demands subjectifying or objectifying work action. Usually, we assume that in situations of low uncertainty, i.e. if means and end can be easily identified, objectifying work action is appropriate while tacit knowledge, experience and also sub-conscious and bodily awareness (including hearing, smelling as well as empathy) are useful guides for unexpected and uncertain situations (ibid., pp. 4-7). This mirrors the notion that tacit knowledge is particular, spatially, temporally and contextually limited knowledge which is not necessarily available for transfer (see most prominently Polanyi 1966 [2009]).⁶ The accompanying concept of living labouring capacity relates to the concept of “Arbeitsvermögen” borrowed from Marx’ conceptual apparatus (for a deeper theoretical discussion, see Pfeiffer 2014). Similar to subjectifying work action, the concept encompasses the variety of human capacities to do work and labour which go beyond the rather simple processing idea encapsulated in the objectifying work action. It is especially noteworthy that the labouring capacity implies that it is increasingly needed the farther the technological development proceeds (Pfeiffer 2016, p. 7).

Research shows that both concepts are present in all work environments, although the increased acceptance they received (or more prominently the related concept of tacit knowledge, see above) is limited to occupations deemed to be non-routine jobs in the routine-non-routine dichotomy (cf. ibid., p. 7). Both concepts cumulate in the notion of “experience-based knowledge work” which contains the three constituting aspects (1) experience, (2) knowledge and (3) work.

With regard to assembly, Pfeiffer (ibid., p. 7) notes “there is no such thing as *the* assembly experience” (emphasis added). In contrast, the experience or the experiential knowledge which enables workers to conduct subjectified work action is build up in relation to a specific (assembly) work in a specific company and also at a specific time. Crucially, this experience - due to its uncodified nature - is difficult to perceive. It is not present in a formalised body of knowledge

⁶ I dispense with a deeper discussion of the issue of tacit knowledge in assembly and rely on the conceptual tool kit which Pfeiffer provides. Pfeiffer’s concepts are sufficient to make my argument in relations to social networks which should apply analogously to arguments based on tacit knowledge. However, the conceptual task to properly relate to the literature on tacit knowledge would undoubtedly also be an interesting avenue for research.

which can be easily transferred to others or related to in order to explain the functioning of a work process. As long as everything runs smoothly and as expected, the presence of experience which enables workers to cope with deviations from the codified work process can hardly be seen. This leads to the paradoxical situation in which the value of experience is ignored in spite of its central importance. Skilled worker regard their experience as self-evident while semi-skilled worker perceive their experience as irrelevant in contrast to their lacking “formal” skills (Pfeiffer 2016, p. 8). However, these formal skills alone, which aim at the ability to conduct objectified work action, are not suited for today’s production processes (ibid., p. 8). This empirical observation is supported by Pfeiffer’s results which illustrate the importance of experience even in “routine” jobs. Additionally, the “unskilled” workers often have a better awareness of the influence of their experience than their supervisors (ibid., p. 11). Nevertheless, companies have partially understood the crucial role which experience plays in assembly and involve experienced workers in innovation and organisational learning processes (ibid., pp. 19-21).⁷

Most importantly for my argument is the question how the capacity to subjectifying work action is build up, adapted and transferred. The questions who has which kind of experience and how the subjectified work action of multiple workers is combined is pivotal. As mentioned above, experience is not codified and, consequently, it cannot be transferred in formalised ways. Instead, personal experience is partially transferred during breaks, while looking over a co-worker’s shoulder or during maintenance (ibid., p. 8). Pfeiffer (ibid., pp. 20-21) reports how experienced workers also increase their ability to gain experience by favouring hands-on activities. In addition, she stresses how important sharing of experience is for collective and organisational learning. This transfer of experience cannot be achieved by formal training or group sessions. Instead, experience is passed on when less experienced workers approach “old hands”. It succeeds in concrete situations and “by direct demonstration, by mimicking, and by shared hands-on doing” (ibid., p. 21).

Pfeiffer offers a compelling approach to conceptualise the importance of experience and subjectified work action. However, her approach only shortly discusses the exchange and transfer of experience. The main part of Pfeiffer’s argument is concerned with the way in which the individual works. In consequence, her short comment on the transfer of experience between workers is insufficient to fully account for the social processes on the shop floor and provides a point of departure for further research. In the following section, I will argue that the literature on networks in organisations can shed some light on the question to whom experience is transferred and how experience crosses formal organisational borders. This literature is suited to complement Pfeiffer’s approach with a conceptual and methodical toolkit to investigate the relational embeddedness of the working process. Therefore, the section will begin with an overview of relevant parts of this field of research.

⁷ Many experienced workers actually want to make use of this ability and participate enthusiastically in these processes (Pfeiffer 2016, p. 20).

3 Networks in Organisations and Networks in Assembly

When a shift ends, not just shift logs, but many less formal information and knowledge is handed onto the next shift's workers. The sharing of experience and information does not stop at working group or shift boundaries (Pfeiffer 2016, p. 21). This example illustrates the importance of informal networks which permeate organisations and production plants besides formal networks. The phenomenon of informal networks, which do not necessarily follow formal organisational charts, is well known in social network research (see for example Krackhardt and Hanson 1993; Krackhardt and Kilduff 1990; Rank 2008; Rank, Robins, and Pattison 2010). The research on this issues covers a wide range of topics reaching from performance in general (e.g. Sparrowe et al. 2001; Cummings and Cross 2003), performance in commonly known knowledge-intensive work environment (e.g. Cross and Cummings 2004), job design (see Kilduff and Brass 2010) to knowledge creation and sharing (e.g. Cross, Parker, and Borgatti 2002) and the relation between job routine and intra-organisational social structure (see Hage and Aiken 1969). The approach suits Pfeiffer's if we assume that experience sharing does not occur at random but follows the affiliations of workers. This assumption is plausible if we recall the Pfeiffer's (2016, pp. 21-22) report on experience sharing: Formal measures fail to facilitate the flow of experience.⁸ While the formal assignment of less experienced to more experienced workers (which would constitute a formal tie) without doubt would allow for the sharing of experience, the informal affiliations influence who shares breaks and chats or maintains other informal modes of contact which provide the platform to exchange experience. Additionally, the distinction between objectified and subjectified work action in situations of certainty and uncertainty is mirrored in the assertion that the formal organisation structures standard modes of production while organisations need to rely on informal networks to cope with unexpected situations (Krackhardt and Hanson 1993, p. 104).

While formal organisation implies a network between tasks and workers (cf. Brass 1981), informal networks do not necessarily get established along these lines. In contrast, Rank's (2008) empirical investigation showed that formal ties are ignored on a repeated basis. This result increases the importance to account for informal networks, but also illustrates the double-sided nature of these networks. Depending on the process and the structure, informal networks can facilitate or hamper performance, change processes or knowledge sharing (for performance, see Soda and Zaheer 2012; for change processes, see McGrath and Krackhardt 2003).

Despite their pivotal role in organisational processes and work environments, people lack the skill to correctly assess the network which surrounds them. While most people correctly identify ties among person to whom they are connected, they often fail to capture the broader social structures (cf. Krackhardt 1987; Freeman 1992). The term Cognitive Social Structure (CSS) has sparked

⁸ However, what constitutes formal measures is changing as well. Newly available data and respective data scientists attempt to optimise knowledge exchange not just on the formal organisational level but also on the level of informal interactions (cf. Pentland 2014).

research to shed light on the relation between perceived networks (CSSs) and actual existing ties (for an overview, see Brands 2013). Kilduff et al. (2008) argue that CSSs enable cognitively constrained actors to keep track of the myriad of possible ties which might surround them. The crucial aspect is that CSSs do not constitute mistakes of incapable actors but are “perceptions [which] are real in their consequences” (Krackhardt 1987, p. 128). For example, the perceived ties limit the number of persons which appear approachable for advice in the broader network (cf. Brands 2013, p. 96). Krackhardt (1990) therefore argues that an accurate perception of the surrounding social structure can be a source of power. In general, the discussion about CSSs mirrors Pfeiffer’s (2016, p. 11) remark that “unskilled” workers often more accurately perceive the role of their experience than their supervisors. Analogously, socially distant supervisors are likely to fail to correctly capture the networks among the supervised and therefore also do not know about the relations through which experience is passed on.

The importance of informal networks also points to the question how those networks form. In general, homophily influences ties in every kind of network. Similar persons - irrespectively of the foundation of their similarity - are very likely to form bonds with each other while ties between persons who differ are more likely to dissolve (McPherson, Smith-Lovin, and Cook 2001). Klein et al. (2004) investigate personality traits as causes for network centrality. They find that education and emotional stability are key predictors of centrality. Mehra, Kilduff, and Brass (2001) report high centrality for persons with high self-monitoring. Furthermore, they show how both traits positively influence work performance.

Moreover, networks are not static. Another strand of the networks in organisations literature captures these dynamics with a focus on consciously induced change processes. Many studies conducted in this subfield differentiate between types of change, types of networks and characteristics of the actors to explain the different effects of networks on the success of change processes. For example, in their classical study McGrath and Krackhardt (2003) propose three mechanisms which work in different settings. They argue that trust is of special importance in the case of uncontroversial but widespread changes. Because trust is build up in strong ties, the relation between inter-unit and intra-unit ties influences whether such a change can spread through an organisation (the more inter-unit ties, the stronger the trust-mediated dissemination of the change). If, in contrast, a controversial change is to be implemented, the embeddedness of the cluster must neither be too high nor too low. If an innovative group or cluster is too isolated, the new idea or change cannot spread through the organisation. On the other hand, if the group is well embedded in the organisation, opposition can rise early and bring the controversial change to an early halt. Battilana and Casciaro (2012) take this argument one step further and argue that the amount of structural holes⁹ surrounding an actor increases the likelihood that this actor initiates a diverging

⁹ The concept was formed by Burt (1992). It describes the situation of missing links in a network. Actors which are

change.

The discussion on knowledge sharing and transfer through networks was shaped by the seminal study of Coleman, Menzel, and Katz (1959) which investigated the diffusion of a new drug in a network of physicians. It demonstrated how social network research can illuminate these processes and provide a systematic way to analyse them. Cross, Parker, and Borgatti (2002) offer a more distinguished approach to this topic which was designed to be applied in business contexts. They differentiate between different dimensions of a network - knowledge (knowing who knows), access (to persons with knowledge), engagement (with these people) and safety (of these knowledge sharing ties) - to provide a practical framework for analysis and problem solving. In a related study, Cross and Cummings (2004) empirically show that centrality in the advice and information network and the awareness network (i.e. the network of ties based on the actors mutual rating of expertise) is related to their performance.

However, it has to be noted that the application of network analysis techniques in organisations is not without ethical problems. For example, network data sometimes cannot guarantee anonymity to protect persons in the investigated network. This is due to usually small sample sizes in organisations and the necessity to collect names to construct the networks. These issues have been addressed but should nevertheless receive the researcher's attention when network analysis is conducted (cf. Borgatti and Molina 2005; Kadushin 2005).

These short spotlights on different aspect of the network in organisations literature demonstrate the manifold insights and areas of application which this field of research provides. As mentioned with regard to the uses of formal and informal networks by actors and to CSS, this strand of research shares aspects with Pfeiffer's (2016) approach. Network research can provide conceptual and methodical tools to analyse the ways in which experience is shared among workers in production plans. The question how networks form can illuminate why certain parts of the employees are isolated in spite of their formal membership in work groups. CSS point to the important aspect that people need to be aware of their surrounding network to tap into their social capital (cf. Coleman 1988). Furthermore, research on change processes and knowledge transfer demonstrate in general that networks strongly influence the success and failure of these changes and the diffusion of knowledge and experience. Regarding this issues at hand, the change and knowledge transfer literature illustrates that working with automatisisation as well as the adoption of automatisisation has to take account of not just subjectifying work action but also the networks which impart the necessary knowledge and experience.

surrounded by structural holes have access to non-redundant information (Burt 1992; see also Burt 2004).

4 Conclusion: Why Should Networks in Assembly Matter?

The previous two sections introduced the approach by (Pfeiffer 2016) and parts of the literature on intra-organisational networks. The last section illustrated how social network research can contribute to further research in assembly work along the lines of Pfeiffer's approach. In summary, this essay made a two-step argument. First, I picked up Pfeiffer's argument that many studies on automatisisation rely on an empirically not support routine-non-routine dichotomy. Second, I argued that the literature on social networks in organisation can complement Pfeiffer's approach by providing a conceptual and methodical toolkit to investigate how the knowledge and experience gets transferred between workers.

This fruitful connection has a general aspect and one which specifically relates to research on robotic automatisisation. In general, the engagement of Pfeiffer's approach with the social network literature should apply in all production contexts. However, it points to blank spots in the social network literature. Most of the reviewed studies were conducted in organisational contexts which are very different from the shop floor. For example, Battilana and Casciaro (2012) investigate change processes in the British National Health services. The study of Cross and Cummings (2004) was conducted among petrochemical engineers and strategy consultants. Already Krackhardt (1990) obtained his empirical results in a small entrepreneurial firm active in information technology. Rank (2008) limits his data collection to the top two management levels of two Germany-based multinational corporations because "strategic decision-making is usually undertaken by top management" (ibid., p. 150). Moreover, parts of the network literature feature a conceptualisation of routine which is similar to the routine-non-routine dichotomy which Pfeiffer (2016, p. 2) criticises. Soda and Zaheer (2012) control their empirical results for the level of "routine". In an older contribution, Hage and Aiken (1969, p. 368) apply a factor analysis on items which cover questions whether "[p]eople here do the same job in the same way every day [..., o]ne thing people like around here is the variety of work (reversed) [..., m]ost jobs have something new happening every day (reversed) [... or t]here is something different to do every day (reversed)". These example show that the engagement between the detailed assessment of assembly work and social network research invites the latter to challenge its concepts and empirical results in new empirical situations.

With regard to robotic automatisisation, this application of concepts and methods of social network research in the field of production can provide valuable insights. Pfeiffer (2016, p. 2) argues that studies on the effects of robotic automatisisation on the labour market have to rely on other studies which examine the processes in the production plants in more detail. These studies can ask questions how workers react to the implementation of new machines (a change process) or how experience with those production techniques is shifted among workers. Moniz and Krings (2016, p. 16) share this call for more micro-evidence. They also stress that social scientists should collaborate with system developers to include organisational and social dimensions in human-robot

interactions. Social network research can provide a way to answer this call and therefore further advance the research on the social factors in the robotic automatisisation of work environments.

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