IEAI Technical University of Munich
School of Social Science and Technology
Institute for Ethics in Artificial Intelligence

Research Brief – June 2022

Algorithmic Scheduling in Industry: Technical and Ethical Aspects

by Charlotte Franziska Unruh, Charlotte Haid, Johannes Fottner, Tim Büthe

Assigning shifts or tasks to employees is omnipresent in the workplace. Though Artificial Intelligence (AI) algorithms are not commonly used in scheduling algorithms (yet), these algorithms have the potential to analyze various data sources as input for scheduling and solve scheduling problems efficiently. However, if AI algorithms are used in scheduling, consideration of ethical aspects will be crucial in order to make the system "human-centered". A step towards such human-centered scheduling could be a system that considers employee preferences in task allocation. This Brief explores the idea of such as system.

From scheduling shifts for nurses in hospitals to allocating tasks to online workers, assigning shifts or tasks to employees is omnipresent in the workplace. While 'simple' scheduling algorithms assign available workers to open tasks, more complex algorithms can consider ergonomic factors, qualifications or individual needs and preferences. Though Artificial Intelligence (AI) algorithms are not commonly used in scheduling algorithms (yet), these algorithms have the potential to analyze various data sources as input for scheduling and solve scheduling problems efficiently. However, if AI algorithms are used in scheduling, consideration of ethical aspects will be crucial. Scheduling can have significant effects on human workers: for example, it can influence a worker's total hours and pay, when shifts are assigned at short notice and workers' ability to make plans and commitments in their personal lives, and shifts may not be aligned with a worker's preferences or capacities. In these cases, shift allocation can influence the well-being and, in the long-term, the physical and mental health of workers. It is therefore important that if scheduling is done by algorithmic systems, ethical and wellbeing aspects are considered. A step towards such human-centered scheduling could be a scheduling system that considers employee preferences in task allocation. This research brief presents our research on developing such a system and outlines ethical principles that can guide the design of algorithmic scheduling systems.

The Issue: Algorithmic Scheduling in Industry 5.0

The fourth industrial revolution, also called Industry 4.0, rapidly changes factories through digital technology and changes in work organization. Production and logistics processes are increasingly digitalized. For example, goods and batches can be tracked throughout the production process, providing real-time data on the status of production systems and potential disruptions. Workers wearing smart gadgets while picking items from warehouse shelves are tracked to measure walking distances, length of breaks or body posture. This 'tracing' data and new algorithmic technologies are increasingly used to inform managerial decision making and adapt the organization of work. Digitalization makes processes more transparent and subsequently also more efficient by uncovering opportunities for improvement.

But transparency also comes at the expense of employees: constant monitoring can lead to increased stress levels and long-term illness. It can also have a negative impact on employee satisfaction and cause employees to leave their company. Industry 4.0, moreover, evokes associations of robots in automated factories, where human workers are no longer needed.

In contrast, the human-centered approach aims to develop technology that has a positive effect on employee satisfaction and employee health in the workplace. For the near- to mid-term future, human workers are unlikely to be replaced, but rather provided with an enhanced skillset to take over core tasks in production and logistics (Sgarbossa 2020). The so-called Industry 5.0 approach complements Industry 4.0 by focusing on sustainable, human-centered, and resilient factories that empower workers and develop their skills (European Commission 2021).

Transparency also comes at the expense of employees

One example of managerial decision making in factories that is changed by Industry 4.0 processes is algorithmic shift and task scheduling. Workers generally rotate between different workstations that require them to perform different tasks. Such rotation is used to reduce ergonomic strain from

repetitive motions and to prevent boredom and fatigue (Mossa 2016). Digitalization offers the possibility to use tracing data of workers as input for scheduling. To ensure sufficient, ergonomic, and efficient staffing, managers need to create a schedule that assigns workers to shifts and workstations – partly by using tracing data as input data. In the following, we consider whether and if so, how such scheduling systems might be designed in a human-centered way.

Algorithmic Scheduling

The basic problem of algorithmic scheduling is that of matching workers and open tasks in different shifts (for example, early and late shift) for a given planning horizon. The horizon can be the next week or the next month, but sometimes short-term rescheduling is necessary because urgent tasks arise, or staff members get sick. The objective is to obtain a schedule that ensures that all tasks are done and observes any additional constraints (Cohrs 2015). Constraints can be legal or organizational – for example, absences due to vacation or illness, working hours, shift lengths, prescribed breaks, or necessary qualifications. Additional constraints can include ergonomic factors or rotation of tasks to enhance worker's qualifications.

Industry 5.0 approach complements Industry 4.0 by focusing on sustainable, human-centered, and resilient factories that empower workers and develop their skills

Shift and task scheduling in logistics is currently carried out by the team manager or by the employees working in a team themselves. In the first case, the manager assigns his employees either manually in an Excel sheet, on a board or with the help of a software (like ipolog or xplan). In the second case, the employees in the team decide who takes on which shift and when and enter themselves into a shift schedule that is pinned up in the production area. While this method can work very well and increase the autonomy of workers, the second method carries the risk that individual members of the group will always be outvoted by others and thus get more difficult or strenuous shifts. Similarly, the allocation by the manager carries the risk that individual employees are favored. Additionally, depending on the number and kind of factors involved, manual shift scheduling or planning shifts in large teams can quickly become difficult.

Shift assignment has a significant impact on the lives of workers

The shifts and tasks that get allocated to workers can have a significant impact on the lives of workers and potentially their families and communities. This is most obvious in the case of workers for online platforms, who do not have guaranteed shifts, so their salary depends directly on the number of shifts they are assigned. In other sectors, shifts can be assigned very flexibly and at short notice. For example, when software predicts staffing needs based on real-time data and allocates shifts accordingly. In the case of a Starbucks worker that was reported in the New York Times in 2014, the worker's erratic schedule generated by scheduling software made it very difficult to combine work with childcare and education (Kantor 2014).

Shift and task allocation software should be subject to stringent impact assessments

Even under more regulated and stable working conditions, it can make a difference to workers which shifts they are assigned. Some shifts or tasks might be more appealing than others, for example because they are better paid or more interesting. The variation of shifts and tasks might influence the number of skills a worker acquires and exercises, their ergonomic load and the perceived fairness of work decisions. In these ways, it is plausible that shift and task allocation could have significant effects on the lives of workers. Given this significance, shift and task allocation software should be subject to stringent impact assessments, which should also include ethical criteria to ensure responsible design, implementation and use of scheduling software.

The Role of AI: Support for Preference-Aware Shift Scheduling Optimization

Human-centricity is one of the European Union's main goals when it comes to Industry 5.0. Europe emphasizes value-based policies and especially the protection of individual rights (European Commission 2021). Applying such human-centered approaches to AI algorithms is challenging, however, as these algorithms are often opaque and not transparent.

AI can be defined as the tasks performed by a machine or as the simulation of certain human intelligence processes using machines (Rebala 2019). It is concerned with understanding and building entities that can compute how to act effectively and safely in a variety of situations (Russell 2020). AI technologies include, for example, natural language processing, computer vision, machine learning or action planning and optimization. In logistics, AI has been used so far primarily for the creation of demand forecasts or route planning. However, data from employees as input for optimization are also increasingly used, for example when smart devices are used to confirm picking up orders in warehouses (Moya Rueda 2018).

Unlike classical optimization algorithms, AI offers the chance to scale up problems quickly and easily

This scalable scheduling problem is often used in large companies where many employees need to be assigned to workstations. The more employees, the more conditions they bring with them – for example, when employees are also assigned across different production halls or work contracts exist that do not allow employees to be sent home at short notice. But, even in medium-sized companies there are numerous areas where many employees are scheduled. The task of creating a schedule can be automated. Software can create schedules based on worker availability, staffing needs and other factors. In a first step, the production itself must be ensured: each workplace needs to be staffed with people. Then, other factors like required qualifications, ergonomic factors or employees' personal developments should be respected.

When it comes to scheduling problems, AI technologies have hardly been used up to now, and more "traditional" algorithmic solutions (such as heuristics and linear programming) still dominate. Constraint Programming, a subfield of AI, solves constraint satisfaction problems by using conditions to decrease the possible solution space before searching for solutions (Naveh 2007). Constraint Programming is particularly efficient for solving highly constrained problems or problems that only require a feasible, but not necessarily optimal, solution (Ernst 2004). Unlike classical optimization algorithms, AI offers the chance to scale up problems quickly and easily. If the number of employees allocated in the system increases or the amount of data per employee increases, AI still has the possibility to find a reasonable solution in a short time. Linear programming fails with large amounts of data due to the computing time and the goal of solution optimization.

Our scheduling system uses constraint programming for allocation and is human-centered.

In the research project "A Human Preference-Aware Optimization System"[1] we look at the particular use case of scheduling in logistics. Here, employees with certain preferences and qualifications for workplaces are assigned to available workstations. Compared to previous scheduling systems, we extend the input data with preferences of employees: each employee can specify up to four preferences for workstations. This can be, for example, whether they prefer to work in a team or alone or whether they like to work with more technical support or without. Our constraint programming algorithm suggests possible shift schedules based on those preferences, with additional information such as the number of shifts per employee or the individual score of fulfilled preferences per employee. The schedules could be provided digitally on a tablet or the manager's computer.

[1] See a Project overview on the IEAI webpage: https://www.ieai.sot.tum.de/research/a-human-preference-aware-optimization-system/

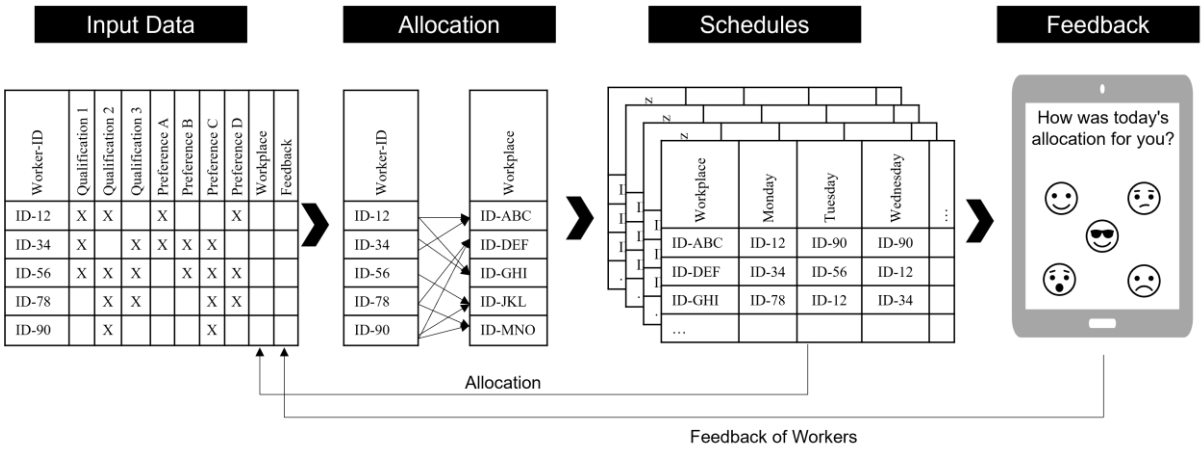

Figure 1 Illustration of the shift planning system developed in the project. Source: Haid et al. 2021.

The manager can then decide which suggestion schedule is the most suitable and apply it. When working a day or a week with the applied schedule, employees can give their feedback on the current schedule. This could be provided by an app on the worker's smartphone where they can enter feedback or with a tablet next to the factory exit – similar to feedback-station in hotels or exhibitions.

Risks and Chances of Artificial Intelligence: Insights for Algorithmic Scheduling

Numerous ethical frameworks for the development and regulation of AI have been developed over the last years (Jobin, Ienca, and Vayena 2019). We use a framework of ethical principles proposed by Cowls and Floridi (2018). Cowls and Floridi synthesize existing sets of principles and suggest that they can be well captured by the four traditional bioethical principles of beneficence, non-maleficence, autonomy, and justice, as well as an additional principle of explicability. The principles provide a framework which might be used in the prospective design or retrospective evaluation of algorithmic scheduling systems like the one just described.

Algorithmic scheduling might contribute to the well-being of workers by allocating tasks to workers, which satisfy their personal needs or preferences

Photo: Syda Productions/shutterstock.com

The principle of beneficence says that AI should promote 'the well-being of people and the planet' (Cowls and Floridi 2018, 8). There is a significant literature on the value of well-being at the workplace, particularly in organizational psychology. Hedonic views on well-being at work consider subjective feelings of positive affect, whereas eudaimonic well-being focuses on human flourishing, a concept that goes beyond subjective happiness and includes the satisfaction of needs and the exercise of capacities (Fisher 2014, 2–4). If done right, algorithmic scheduling might contribute to the well-being of workers by allocating tasks to workers, which satisfy their personal needs or preferences. For example, one worker might find morning shifts more pleasurable, as she gets tired and grumpy in the afternoon. Another worker might prefer tasks that can be done walking rather than sitting to get more movement during the day. Yet another worker might wish to develop their skills in

different areas and therefore aims to take on more new tasks.

The principle of non-maleficence says that AI should do no harm. As Cowls and Floridi (2018, 8–9) point out, this could be understood in various ways. For example, harm can be caused by the AI itself or by the human agent who uses AI. An individual can be harmed by experiencing a loss of welfare or a violation of rights. In the context of AI, a right that is commonly mentioned is the right to privacy. In fact, some have argued that the right to privacy is key not only to protect one's personal sphere, but also essential to the functioning of democracy (Véliz 2021, 11). Surveillance and monitoring at work have increased since the start of the COVID-19 pandemic (Trades Union Congress 2022). Digital technologies have enabled intrusive and far-reaching employee surveillance, for example, through video and voice recording, tracking and analysis of online activities or productivity apps and performance ratings. Regulation for employee surveillance is urgently needed (Ajunwa, Crawford, and Schultz 2017).

Algorithmic scheduling can violate the privacy rights of employees

Algorithmic scheduling that considers individual needs and preferences of workers needs access to potentially sensitive data. This gives rise to problems around data security and potential misuse (e.g. for intrusive performance measurement). Algorithmic scheduling can violate the privacy rights of employees. Moreover, given power relations at workplaces, it can be very difficult to obtain informed consent from workers. Moreover, as Moradi and Levy (2020) argue, algorithmic scheduling is sometimes used by firms to shift their business risks onto employees. Through the analysis of real-time data, firms can assign shifts flexibly and at short notice for the duration of predicted demand. The risk of too much or too little staffing is then assumed not by the firms, but the workers. Flexibility can be seen as both an opportunity and a risk: while some employees might enjoy having more flexibility, it might also make advance planning more difficult (Haid et al. 2021, 910).

Photo: Nejron Photo/shutterstock.com

Autonomy is the power of individuals to make their own choices and to live their lives by their chosen values. As a central value in ethical theory, it underlies, for example, Kantian ethics. Autonomy is also a value that has received a lot of discussion in the context of work (Roessler 2012). In many traditional workplaces and employer-employee relationships, the employee is not fully autonomous. This seems true particularly of low-skilled, low-paid jobs. Work at the factory line or in warehouses is often highly repetitive and minutely structured. There is not much choice or discretion regarding when to work, which tasks or projects to work on, in which order and in what exact way to fulfil the tasks. Increased autonomy is one of several variables that can increase feelings of meaningfulness and thereby job satisfaction and motivation (Rosso, Dekas, and Wrzesniewski 2010, 103). Algorithmic scheduling can exacerbate the loss of autonomy by enabling increasing work fragmentation. On the other hand, self-service shift swapping apps (e.g. (Williams et al. n.d., 25)) might increase autonomy over working times and hours by replacing top-down shift scheduling mechanisms.

Photo: FotoArtist Stockphoto/shutterstock.com

Employee participation and adaptable solutions might be key to fairness in algorithmic scheduling

According to Cowls and Floridi (2018, 11), justice in the context of AI ethics can mean eliminating discrimination, ensuring the fair distribution of benefits of AI or preventing harms to social structures. In general, justice concerns distribution, for example, of resources or welfare. What constitutes fair distribution is controversial in ethical theory. Moreover, not all fairness distributions lend themselves easily to the formalization necessary for encoding them in computer programs, and a significant number of fairness definitions for AI have been proposed. For example, Verma and Rubin (2018) consider 20 different definitions of fairness, including statistical parity, treatment equality and counterfactual fairness, which they illustrate by applying the definitions to a case of gender-related discrimination regarding loan requests.
Algorithmic scheduling can conflict with justice if it allocates shifts and tasks unfairly. Fairness in scheduling is a significant area of research, and there are different ways to design 'fair' schedules, which can come into conflict (for an overview, see Wolbeck (2019)). When scheduling takes human preferences into account, the question is how to distribute tasks and shifts according to preferences in a way that is fair. It is important to understand that there will be no one-size-fits-all solution. This is why it will be important to be transparent about rules about scheduling, involve workers in setting these rules, and make systems configurable and adaptable to fit workers' wishes, circumstances, and corporate culture.

Photo:StratfordProductions/shutterstock.com

Employee participation, communication and training are crucial for intelligible and accountable systems

The fifth principle, which Cowls and Floridi add to the four traditional bioethical principles, is explicability. Explicability means intelligibility of algorithmic processes and decisions, and accountability for them (Cowls and Floridi 2018, 12). To meaningfully consent into the use of AI, to shape its development and to guard against harmful use, people must be able to understand where algorithmic systems are used and what they can and cannot do. Further, it must be clear who can be held responsible for algorithmic decisions. In the case of algorithmic scheduling, transparency requires that it is made explicit and understandable which rules are used, and accountability requires at least that a human manager should be in the loop, able to make manual changes and act as a contact person for employees who wish to make changes or complaints.

It is important to understand that there will be no one-size-fits-all solution

Final Thoughts

Algorithmic scheduling technologies can have significant effects on workers' lives. For this reason, regulators, companies and users of those technologies should consider ethical principles in their impact assessments. We suggested that scheduling algorithms might make work more pleasant by considering worker preferences and might increase the autonomy of workers if they offer workers more choice about when and how they work. We further mentioned some of the risks that can arise, arguing that there are serious concerns about the optimization of schedules that comes at the cost of workers' well-being, autonomy and privacy. This results in the conclusion that there might not be a one-size-fits-all solution algorithmic scheduling that is fair and responsive to the needs, preferences and wishes of stakeholders. For this reason, responsible design of algorithmic scheduling systems should be done in close collaboration with affected workers, as well as

employers and other stakeholders. Our future research on this topic includes a refinement and adaptation of our prototypical scheduling system into a specific use case, involving workers in the process of adapting the scheduling system to the needs and wishes of a specific company.

Acknowledgements

We thank Jaclyn Hovsmith for her support in preparing this research brief. The project "A Human Preference Aware Optimization System" is funded by the Institute for Ethics in AI at the Technical University of Munich.

References

Ajunwa, Ifeoma, Kate Crawford, and Jason Schultz (2017). Limitless Worker Surveillance. *California Law Review* 105 (3): 735–76. https://doi.org/10.15779/Z38BR8MF94.

Cohrs, C. (2015). Personaleinsatz und Personalfreisetzung. In J. Rowold (Hrsg.), Human Resource Management. Lehrbuch für Bachelor und Master (Lehrbuch, 2., vollst.korr. und verb. Aufl., S. 145-158). Berlin: Springer Gabler

Cowls, Josh, and Luciano Floridi (2018). Prolegomena to a White Paper on an Ethical Framework for a Good AI Society. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3198732.

European Commission, Directorate-General for Research and Innovation, Breque, M., De Nul, L., Petridis, A., *Industry 5.0 : towards a sustainable, human-centric and resilient European industry, Publications Office, 2021,* https://data.europa.eu/doi/10.2777/308407

Ernst, A., Jiang, H., Krishnamoorthy, M., Sier, D. (2004) Staff scheduling and rostering: A review of applications, methods and models. European Journal of Operational Research.

Fisher, Cynthia D. (2014). Conceptualizing and Measuring Wellbeing at Work. In *Wellbeing*, 1–25. John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118539415.wbwell018.

Haid, Charlotte, Charlotte Unruh, Isabel Pröger, Johannes Fottner, and Tim Büthe. 2021. 'Personaleinsatzplanung in Der Logistik: Berücksichtigung von Mitarbeiterpräferenzen in Der Zuteilung von Arbeitsplätzen Mithilfe von Artificial Intelligence'. Zeitschrift Für Wirtschaftlichen Fabrikbetrieb 116 (12): 908–12. https://doi.org/10.1515/zwf-2021-0160.

Jobin, Anna, Marcello Lenca, and Effy Vayena (2019). The Global Landscape of AI Ethics Guidelines. *Nature Machine Intelligence* 1 (9): 389–99. https://doi.org/10.1038/s42256-019-0088-2. *Economics* 171 (4): 471-477. https://doi.org/10.1016/j.ijpe.2015.06.017.

Kantor, Jodi (2014). Working Anything but 9 to 5. *The New York Times*, 13 August 2014, sec. U.S. https://www.nytimes.com/interactive/2014/08/13/us/starbucks-workers-scheduling-hours.html

Moradi, Pegah, and Karen Levy (2020). The Future of Work in the Age of AI: Displacement or Risk-Shifting? In *The Oxford Handbook of Ethics of AI*, edited by Markus D. Dubber, Frank Pasquale, and Sunit Das, 269–88. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190067397.013.17.

Mossa, G, F. Boenzi, S. Digiesi, G. Mummolo, and V.A. Romano (2016). Productivity and ergonomic risk in human based production systems: A job-rotation scheduling model. *International Journal of Production*

Moya Rueda F, Grzeszick R, Fink GA, Feldhorst S, Ten Hompel M (2018). Convolutional Neural Networks for Human Activity Recognition Using Body-Worn Sensors. *Informatics*. 5(2):26. https://doi.org/10.3390/informatics5020026

Naveh, Y., Richter, Y., Altshuler, Y., Gresh, D.L., Connors, D.P. (2007). Workforce optimization: Identification and assignment of professional workers using constraint programming. IBM J. Res. & Dev.

Rebala, G., Ravi, A., & Churiwala, S. (2019). An Introduction to Machine Learning. In Studies in Computational Intelligence 975.

Roessler, Beate (2012). Meaningful Work: Arguments from Autonomy*. *Journal of Political Philosophy* 20 (1): 71–93. https://doi.org/10.1111/j.1467-9760.2011.00408.x.

Rosso, Brent D., Kathryn H. Dekas, and Amy Wrzesniewski (2010). On the Meaning of Work: A Theoretical Integration and Review. *Research in Organizational Behavior* 30 (January): 91–127. https://doi.org/10.1016/j.riob.2010.09.001.

Russell, S. J.; Norvig, P.: (2020). Artificial Intelligence – A Modern Approach. Boston: Pearson.

Sgarbossa, Fabio, Eric H. Gross, W. Patrick Neumann, Daria Battini, and Christoph H. Glock (2020). Human factors in production and logistics systems of the future. *Annual Reviews in Control* 49: 295-305. https://doi.org/10.1016/j.arcontrol.2020.04.007.

Trades Union Congress (2022). Intrusive Worker Surveillance Tech Risks "Spiralling out of Control" without Stronger Regulation, TUC Warns. https://www.tuc.org.uk/news/intrusive-worker-surveillance-tech-risks-spiralling-out-control-without-stronger-regulation.

Véliz, Carissa (2021). Privacy and Digital Ethics after the Pandemic. *Nature Electronics* 4 (1): 10–11. https://doi.org/10.1038/s41928-020-00536-y.

Verma, Sahil, and Julia Rubin (2018). Fairness Definitions Explained. In *Proceedings of the International Workshop on Software Fairness*, 1–7. Gothenburg Sweden: ACM. https://doi.org/10.1145/3194770.3194776.

Williams, Joan C., Susan J. Lambert, Saravanan Kesavan, Peter J. Fugiel, Lori Ann Ospina, Erin Devorah Rapoport, Meghan Jarpe, et al. n.d. (2015). Stable Scheduling Increases Productivity and Sales. The Stable Scheduling Study. Accessed 24 August 2021. https://worklifelaw.org/publications/Stable-Scheduling-Study-Report.pdf.

Wolbeck, Lena (2019). Fairness Aspects in Personnel Scheduling. https://doi.org/10.17169/refubium-26050.