Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 200 (2022) 505–516

Procedia Computer Science

www.elsevier.com/locate/procedia

3rd International Conference on Industry 4.0 and Smart Manufacturing

A value sensitive design approach for designing AI-based worker assistance systems in manufacturing

Susanne Vernim[a]*, Harald Bauer[a], Erwin Rauch[b], Marianne Thejls Ziegler[c], Steven Umbrello[d]

[a]*Institute for Machine Tools and Industrial Management (iwb), Technical University of Munich, Boltzmannstr. 15, 85748 Garching, Germany*
[b]*Faculty of Science and Technology, Free University of Bozen-Bolzano, Universitätsplatz 5, Bozen-Bolzano 39100, Italy*
[c]*Chair of Business Ethics, Technical University of Munich, Arcisstr. 21, 80333 Munich, Germany*
[d]*Institute for Ethics and Emerging Technologies, University of Turin, Via Sant'Ottavio 20, Torino 10124, Italy*

Abstract

Although artificial intelligence has been given an unprecedented amount of attention in both the public and academic domains in the last few years, its convergence with other transformative technologies like cloud computing, robotics, and augmented/virtual reality is predicted to exacerbate its impacts on society. The adoption and integration of these technologies within industry and manufacturing spaces is a fundamental part of what is called Industry 4.0, or the Fourth Industrial Revolution. The impacts of this paradigm shift on the human operators who continue to work alongside and symbiotically with these technologies in the industry bring with it novel ethical issues. Therefore, how to design these technologies *for* human values becomes the critical area of intervention. This paper takes up the case study of robotic AI-based assistance systems to explore the potential value implications that emerge due to current design practices and use. The design methodology known as Value Sensitive Design (VSD) is proposed as a sufficient starting point for designing these technologies *for* human values to address these issues.

Peer-review under responsibility of the scientific committee of the 3rd International Conference on Industry 4.0 and Smart Manufacturing

Keywords: Industry 4.0; value sensitive design; VSD; engineering ethics; AI; assistance systems;

* Corresponding author. Tel.: +49-89-289-15514; fax: +49-89-289-15555.
E-mail address: susanne.vernim@iwb.tum.de

Peer-review under responsibility of the scientific committee of the 3rd International Conference on Industry 4.0 and Smart Manufacturing
10.1016/j.procs.2022.01.248

1. Introduction

1.1. Motivation, state of research and research gap

Industry 4.0 technologies and the ongoing trend towards the application of Artificial Intelligence (AI) in manufacturing will influence the design of manufacturing systems and workplaces. AI will become one of the most critical drivers for realising intelligent factories in manufacturing, perhaps more than any other technological innovation in recent years. Cyber-physical production systems (CPPS) use AI-based worker assistance systems to control aspects of physical production and have the potential to substantially improve cost-benefit structures and increase economic value in manufacturing systems [2]. The potential for these assistance systems to increase efficiency and enhance sustainability will significantly impact future production [3].

In recent years, research has been drawing attention to the human-centric design of CPPS [4] and to the genesis of the 'Operator 4.0', a hybrid agent that is the product of a symbiotic relationship between the human and the machine [5] [6]. To move towards more cognitive and intelligent spaces [7], human workers are asked to cooperate with the CPPS and complement the robotic and virtual world of the 'smart factory' in different use cases (e.g., decision making, predictive maintenance) and through novel technologies [8] enabling faster and more intuitive workflows [9]. Future workplaces in production will be augmented with multiple kinds of worker assistance systems combining technologies like collaborative robotics, voice-enabled interaction, augmented reality, and natural human-machine interfaces with AI, thus giving birth to intelligent digital assistants [10]. Much of the incentive towards these new types of symbiotic technologies is a consequence of the rising requirements in manufacturing companies, leading to rising requirements for production workers. Given that, technological (digital) solutions support workers in fulfilling their tasks, these systems prove invaluable in achieving production goals.

Notwithstanding, like all technologies, these systems also embody human values. More precisely, the design decisions made in the engineering of these CPPS implicate a host of human values, even if they are not explicit. It has long been the contention of the philosophy of technology that technologies are not value-neutral, purely instrumental, nor purely deterministic [11]. Instead, technologies are interactional, meaning that technologies support and constrain certain social factors, and, likewise, those social factors support and constrain specific technological pathways and futures. This becomes of particular importance when we discuss technologies that employ AI. CPPS often and will increasingly continue to utilise AI. This is because AI offers further possibilities, especially when it comes to human-machine interaction. AI-based on machine learning (ML) and artificial neural networks are often opaque, meaning that how and what it learns is difficult, if not impossible, to trace. Even if explicitly designed, the critical values may ultimately be disembodied by a system in situ. For this reason, even more care has to be taken for how to go about embodying important human values early on and throughout the design of these technologies. An explicit orientation towards designing these worker assistance platforms for human values is currently a lacuna, which this paper aims to address.

Traditional engineering design approaches used for manufacturing systems are mainly based on identifying user needs, their derivation into functional requirements and the definition of physical solutions to satisfy the previously identified specifications [12]. In the past, most system designers have followed the long-term sustainability of the manufacturing system, but mainly only in one single aspect of sustainability, the increase of profitability for the company. More recently, human elements, primarily oriented towards ergonomic design, have been considered to provide an anthropocentric (human-centred) design of manufacturing systems [13], [14]. Over the last few years, an increasing amount of research has tackled the negative environmental impact of manufacturing systems leading to a more "green" design approach where aspects of ecological sustainability have also been considered [15]. Similarly, other researchers have paid closer attention to combining sustainable design with technologies from the Fourth Industrial Revolution, introducing a sustainable enterprise design 4.0 concept [16]. This design approach aims to focus on those Industry 4.0 technologies that enhance the positive impact of economic or ecological aspects and social aspects based on the manufacturing system design. However, most traditional manufacturing system design approaches do not consider ethical issues in the design, while ethics should be evident in completing the quality of design solutions [17]. Therefore, we still see a gap in research on the ethical aspects of the design of manufacturing systems so far, as ethical considerations play a minor role in engineering disciplines. In addition, research needs to approach the challenge of implementing actual values in actual design processes. We want to reduce this gap by pointing out this shortcoming in this work and presenting the value sensitive design approach to give engineers and technicians a systematic instrument for addressing and integrating ethical aspects into future manufacturing system design. In addition, there has been little work that addresses the development of ethically based design approaches.

1.2. Research objectives and contributions

The paper will employ the value sensitive design (VSD) approach [6] to a specific case of technology design; A robotic AI-based assistance system (in the following named "case AS (assistance system)") is currently being constructed at the Smart Mini Factory lab at the Free University of Bolzano (Unibz). VSD is a principled approach to technology design constituted by a tripartite methodology of three different investigations. These are conceptual, empirical, and technical investigations undertaken either consecutively, in parallel, or iteratively. They involve, respectively, 1) conceptual investigations into values and possible value tensions, 2) empirically investigating the relevant stakeholders to determine their various values as well as define how to understand their values and priorities, and 3) selecting and evaluating the technical limitations of the technology itself and their support and/or constraints for human values. This paper is organised per this tripartite structure and thus explores the technical, empirical, and conceptual vectors of an AI-based worker assistance system in manufacturing. The VSD approach is chosen compared to other methodologies (e.g. axiomatic design [12], manufacturing system design decomposition (MSDD) [18], human-technology-organization analysis [19]) due to its iterative, interactional, and transdisciplinary precepts towards the principled embodiment of human values as a function of the design of technologies. The tripartite structure will enable us to present an illustrative example of how design teams can carry out this methodology for robotic AI-based assistance systems as it allows that technical requirements to a system are coordinated with the values of relevant stakeholders. In this context, the technical aspect is the case AS in its current design. The empirical element concerns the identification of relevant stakeholders, and the conceptual part focuses on appropriate values (see Fig. 1).

The following second section will outline the use case and determine the initial technical features and potential value constraints of the assistance system in question (i.e., technical investigations). The third section will identify the relevant stakeholders in future working environments/production lines (i.e., empirical investigations). Section 4 will determine the values of relevant stakeholders that can and should be considered when applying VSD (i.e., conceptual investigations). Section 5 will revisit the technical investigation, evaluate how the case AS in its current design/version supports or constrains the values of relevant stakeholders, and recommend how these values can be accounted for in potentially subsequent redesign cycles of this system.

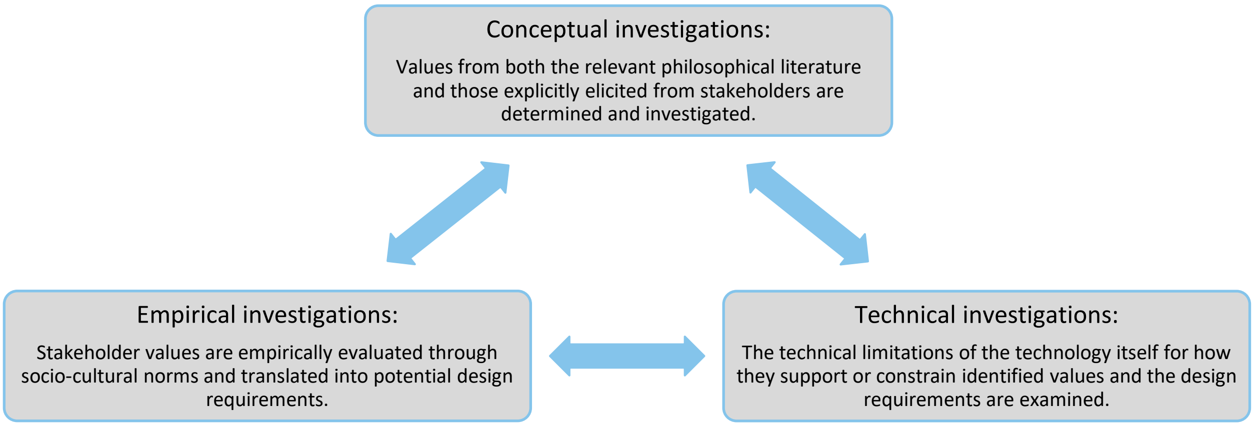

Fig. 1. The recursive VSD tripartite framework (Source: [1])

2. Technical investigations of the use case: The robotic AI-based assistance system of Unibz

Since 2019, the Smart Mini Factory lab at Unibz has developed an AI-assisted and human-robot collaborative assembly workstation representing an intelligent CPPS. The product produced at this workstation for didactic and research purposes is a pneumatic cylinder (small to medium product with low weight and about 20 components to be assembled). The system is depicted in Fig. 2 and shows the AI-assisted workplace, where the operator is supported by a collaborative robot (cobot) as a physical assistance system. In addition, [3] also mention sensorial and cognitive assistance systems to support the operator and collaborating machines in scene understanding and decision-making. Such a modern and futuristic workplace includes, in addition to cobots also sensors for data collection from the production environment. In the assistance system depicted in Fig. 2, the sensing system is composed of a ZED-mini stereo camera and a PSENscan 2D lidar scanner. The operator motion is captured and modelled with a constant acceleration Kalman filter for each kinematical joint of the operator body, including legs, arms, and head. A stereo camera observes the upper part of the operator's body, and the legs are visible by the lidar scan. In terms of safety, tracking the operator's motion allows one to understand where critical body parts are located in real-time. Therefore, it is possible to promptly modulate the relative velocity between the operator and the robot or stop the robot's motion to prevent any dangerous circumstances. In addition to sole human tracking and safety purposes, the experimental workstation is still under development. In the future, it is intended to predict the operator's tasks, thus adapt the peripheral workstation and hardware to the individual work sequence of the operator and automatically adapt the workstation when the operator changes from one product variant to another. Applying natural human-machine interaction technologies like gesture or voice control, the performance and flexibility of the system can be further increased. Similar experiences with AI and computer vision-based technologies have proven to deliver also a large amount of real-time data that can be used for data analytics and for optimising the production schedule in nearly real-time [20]. Other promising applications are related to data for being visualised to the human operator via augmented reality (AR) headsets or using AI algorithms paired with computer vision-generated data to conduct in-process quality inspection/control. A further possible application of AI in manufacturing is implementing production chatbots for quick information retrieval to support the operators in decision-making.

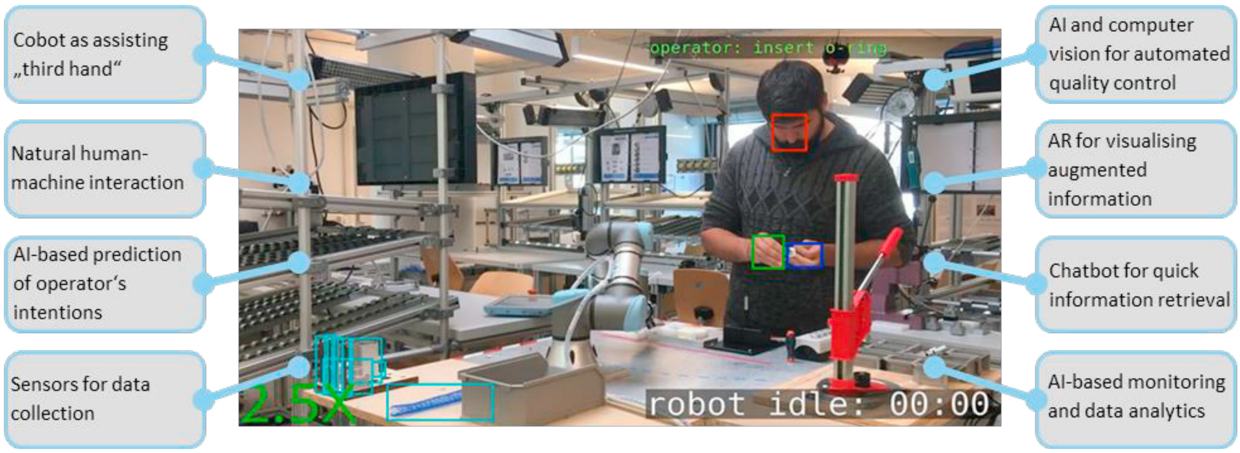

Fig. 2. Robotic AI-based worker assistance system in manufacturing

3. Empirical investigations of the case AS: Stakeholder identification and elicitation/enrollment

As mentioned initially, this paper is comparatively unique in its approach given that previous works have primarily focused on conceptual and empirical investigations when appropriating VSD for any particular technology [21], whereas this paper centres on a primarily technical investigation given the novelty of the assistance system in question.

Regardless, to demonstrate VSD proper in this context, it merits speaking at least cursorily on these two other investigations within the broader context of implementing VSD.

There are various tools that VSD has appropriated from the social sciences for engaging in such empirical investigations, including the ones listed in the following Table 1. Identifying who the stakeholder groups are, legitimating them, and eliciting their values for the given project is especially important in this step.

Table 1. Summary of seven Value Sensitive Design empirical investigation methods. (Source: [22] [Modified]).

Method	Overview and key references
Stakeholder Analysis	Identify individuals, groups, organisations, institutions, and societies that might reasonably be affected by the technology under investigation and in what ways. Two overarching stakeholder categories: (1) those who interact directly with the technology, direct stakeholders; and (2) those indirectly affected by the technology, indirect stakeholders. See [23], [24], [25], and [26].
Stakeholder Tokens	Playful and versatile toolkit for identifying stakeholders and their interactions. Stakeholder tokens facilitate identifying stakeholders, distinguishing core from peripheral stakeholders, surfacing excluded stakeholders, and articulating relationships among stakeholders. See [27].
Value Sketch	Sketching activities as a way to tap into stakeholders' non-verbal understandings, views, and values about a technology. See [28] and [29].
Value-oriented Semi-Structured Interview	Semi-structured interview questions as a way to tap into stakeholders' understandings, views, and values about a technology. Questions typically emphasise stakeholders' evaluative judgments (e.g., all right or not all right) about a technology as well as rationale (e.g., why?). Additional considerations introduced by the stakeholder are pursued. See [30], [31], [32], and [25].
Scalable Assessments of Information Dimensions	Sets of questions constructed to tease apart the impact of pervasiveness, granularity of information, proximity, and other scalable dimensions. Can be used in interview or survey formats. See [30], [23], and [33].
Value Dams and Flows	Analytic method to reduce the solution space and resolve value tensions among design choices. First, design options that even a small percentage of stakeholders strongly object to are removed from the design space — the value dams. Then of the remaining design options, those that a good percentage of stakeholders find appealing are foregrounded in the design — the value flows. Can be applied to the design of both technology and social structures. See [34], [25], and [35].
Value Sensitive Action-Reflection Model	Reflective process for introducing value sensitive prompts into a co-design activity. Prompts can be designer or stakeholder generated. See [36].

In the empirical investigation of the case AS in this contribution, we conducted an extensive stakeholder analysis described in the following.

The assisted workstation in Fig. 2 mainly is constructed as a workstation for operators on the factory floor. Still, other parties are involved and get in touch with the system during set-up, usage, and maintenance in production. Consequently, two different types of stakeholders can be distinguished. Stakeholders are persons with a stake in the production facilities. In VSD, in general, and in this work in particular, we distinguish between (i) direct and (ii) indirect stakeholders. A direct stakeholder is an individual or a group who directly interacts with the technology [22]. Therefore, in terms of VSD, the technology/system should be designed explicitly for these stakeholders and consider their requirements. Indirect stakeholders, on the contrary, are individuals or groups of persons who are impacted by the technology but do not directly interact with it. When a small drone flies over a bystander, she may be bothered by its sound and presence, and her privacy might be violated. The bystander in this example would be an indirect stakeholder. In contrast, the drone operator would be a direct stakeholder, as she is interacting directly with the technology.

For the workstation in Fig. 2, the direct stakeholders are mainly the operators on the shop floor working directly with or closely next to the system. But also their immediate manager and the technician belong to this group. The technician is the person who will take care of the maintenance of the system in the event of a failure or a production or manufacturing change and undertakes its adjustment or repair. The direct manager on the shop floor acts as the first contact for all employee questions or rising problems. In this function, they also interact with the system under certain circumstances, for example, to clarify instruction or to see for him/herself how the system is being implemented. Therefore, they are also counted as direct stakeholders.

The indirect stakeholders of the workstation are the executive managers, who bear the overall responsibility for production and the used technologies there from a financial, legal, and organisational perspective. In addition, the workers' councils can also be described as indirect stakeholders since they are responsible for the wellbeing of the employees and are involved in all decisions concerning the design of the workplaces.

The following Table 2 describes the interaction of the relevant stakeholder with each other and directly with the assistance system at the respective workplace. When designing the workplace, so far, only technical considerations were taken into account. The individual values and wishes of the stakeholders concerning their work environment and their interactions were not in focus.

Table 2. Description of the relevant direct and indirect stakeholders for the case study workstation.

Direct stakeholders (interaction with the system in application, so during production)		
Group of stakeholder	*Interaction with the system (= robotic AI-based assistance system)*	*Interaction with other stakeholders/colleagues*
operator	• touching the robot: taking parts, handing over parts • conducting the robot: verbally, manually • receiving information • being monitored: movements, work results	• verbally exchanging information • supporting with tasks • changing workplaces
operator nearby	• receiving information • being monitored: movements, work results	• verbally exchanging information • supporting with tasks • changing workplaces
technician/ maintenance	• programming the robot: set-up, adaption to variants • testing the robot • analysing problems and information (e. g., in case of unexpected break-downs)	• verbally exchanging information • supporting with tasks • changing workplaces
direct manager	• touching the robot: taking parts, handing over parts • conducting the robot: verbally, manually • receiving and giving information • being monitored: movements, work results	• verbally exchanging information • supporting with tasks • deciding in unclear situations
Indirect stakeholders (impacted by the technology without directly interacting with it)		
Group of stakeholder	*Interaction with the system (= robotic AI-based assistance system)*	*Interaction with other stakeholders/colleagues*
worker council	• receiving and giving information (for test purposes only, not during production) • being monitored (for test purposes only, not during production): movements, work results	• verbally exchanging information
executives	• receiving and giving information (for test purposes only, not during production) • being monitored (for test purposes only, not during production): movements, work results	• verbally exchanging information • deciding in unclear situations

Concerning their tasks and responsibilities in the production system, all stakeholders have an individual requirements profile, which defines all necessary competencies and qualifications a person must have to fulfil the work tasks at the respective workplace successfully. Additionally, the work tasks also determine the essential interactions each stakeholder group has with the system on the one hand and other stakeholder groups, respectively colleagues, on the other hand. Those interactions are strongly linked with the workplace requirements, as they describe which competencies a person at this workplace must have and therefore give a prediction about how a person works and behaves. Within VSD, this information can be seen as the value dams and flows and thus serves as a guidepost for the design of the workplace. Within a Smart Factory, the workplace requirements can be subdivided into five requirements categories: flexibility, adaptability to changes, professional competence, teamwork, and system competence [37]. Each category contains several detailed requirements, which can be used to describe typical Smart Factory workplaces. A distinction can be made between "flexibility" in terms of time, function, or location in the deployment of workers. The category "adaptability to changes" comprises requirements which enable human workers to deal with constant changes and new situations. "Professional competence" summarises all competencies the personnel must have to fulfil the tasks at the respective workplace successfully. In contrast, the category "ability for teamwork" consists of all requirements and competencies that empower humans to work together, react to each other, and communicate. "System competence" contains general requirements that are necessary to understand and fulfil a task in a technical working environment, for example, creativity, resilience, or to work under pressure. In combination with information about the level of competence the operator must reach, the personnel department can decide about necessary qualification or organisation measures for the operators. [37]

4. Conceptual investigations through values: Wellbeing, justice and dignity, freedom from surveillance and professional interaction

4.1. Work as a source of meaning and identity

VSD identifies three values as universal: human wellbeing, justice, and dignity [22]. This last section will attempt to connect the three values to the case AS, and for each of the values, the following questions will be asked: Which design feature would promote or violate this value? As the case AS is applied in a production process, we will seek inspiration in research on what makes work meaningful to bridge specific design features to these very general and abstract values. Work constitutes a vital source of identity and can serve as a key to social participation [38]. It contributes to collective life and enables the "cultivation of occupational identities […] and the values of equality, fairness, and justice in the organisation of work." [39]. Therefore, a value sensitive design of the case AS should contribute to the cultivation of these values and enable them to manifest in the working process.

According to a British survey from 2016 of 135 employees in 10 very different occupations, meaning is attached to organisation, job, task, and interaction [40]. The organisation and the job are specific to the production facility in which the case AS is integrated. Thus, an operator could attach more or less meaning to organisation and job depending on the overall organisational mission and product. Assembling technical equipment enabling medical assistance in geographically remote areas (organisation and job) may be experienced as meaningful. However, if the individual's specific contribution is performed in solitude, the task and the interaction could be experienced as less significant. The case AS partly creates task and interaction.

The findings confirm the ones of earlier surveys. [41] conducted surveys in the United States and Korea that compared ten different needs, "each of which has been proposed by prominent psychological theories, to determine which candidate needs can best be supported by data". Based on these surveys, they identified the need to experience oneself as autonomous, competent, and related (ACR) as essential to human nature. The kind of jobs performed in cooperation with fellow citizens and where the challenges are adjusted to individual abilities enable the intersubjective recognition required for human subjects to obtain a sense of identity. System dams and flows define the space of design flexibility relative to stakeholder values as they manifest in job and interaction. The flexibility should be used to optimise the quality of human-machine interaction (i.e. the task) and the interaction between primary stakeholders.

4.2. Wellbeing

The experience of meaning is, according to the survey, not proportional to position in a professional hierarchy; instead, it is derived from the interactional aspect of work. Meaningful work is self-transcendent; its outcome makes a difference to other persons [40]. Though this experience of meaning may not be conditioned by direct gratitude (customer complementing the operator), the employee should see a direct connection between the performed task and the benefit for others (colleagues or customers). To exemplify the opposite, bureaucratic work is often experienced as meaningless because it lacks a direct receiver. To experience oneself as competent, the operators need certain visibility as they interact with the system. Interviewees of the 2016 survey emphasised "the importance of camaraderie and relations with co-workers", that is, professional interaction conveys not only human contact on the professional level but also at a more personal level [40]. The design should aim at intensifying cooperation between operators to integrate human interaction in the production process. Work-process interaction would convey human contact as such and the possibility for a mutual recognition that can make the task self-transcendent. Value sensitivity concerning wellbeing would therefore design the system as an integrative part of a cooperative production process.

4.3. Justice and dignity

Technology is at risk of undermining justice, first of all, due to its risk of reproducing human bias [42]. Thus, the case AS should therefore be designed for various human beings, if possible, including persons with a physical disability. Secondly, the case AS enables surveillance to evaluate operator performance. This could reinforce the power relation between operator and superior. In the words of Foucault: "The success of disciplinary power derives no doubt from the use of simple instruments; hierarchical observation, normalising judgment and their combination in a procedure that is specific to it, the examination" [43]. Detailed surveillance and performance measurement adversely affect productivity and psychological wellbeing because it undermines the operator's ownership of the production process and sense of autonomy [44]. Even if the system works reactively to the operator's movements, the awareness of being performance measured will undermine the operator's experience of autonomy. Lower control of everyday working processes increases the risk of stress and depression, and premature mortality [45].

The purpose of the case AS data collection, therefore, needs to be clear and transparent. It should be made to optimise the machinery to the operator and not control operator performance. The data should be equally available to the operator, technician, and superior. Just as dignity is interconnected with that of wellbeing and justice, so is the experience of oneself as autonomous and competent depending on being related to co-workers. Therefore, the case AS needs to support the kind of interaction that optimises individual autonomy and interconnectedness. A dignifying job as operator of the case AS presupposes visibility in professional interaction and autonomy concerning superiors.

5. Revisit technical investigation: Does the AI-assisted workstation address the identified values?

In this section, we assess the current version of the case AS in section 2 according to Value Sensitive Design as a means for addressing the ethical implications in redesign. With this step, we follow the tripartite methodology starting from an empirical investigation (identifying stakeholders and related requirements), conceptual investigation (values to be implemented), and finally resulting in a technical investigation (redesign of the case AS). In the current form, the system described in section 2 has been designed with traditional methods more or less without ethical considerations. The main goal in the original design was "function" to increase productivity and process quality. Now the question is if this design supports or constrains ethical values and how the system can be redesigned better to satisfy these functions as well as ethical requirements (see Table 3).

Table 3. Assessment of values in the original design and derivation of a value sensitive redesign.

Values	Original design	System redesign
meaning	Currently, no emphasis was placed here.	In a future redesign of the workstation, the meaning of the work should be increased by showing pictures of the final products where the assembled pneumatic cylinder is integrated.
identity (autonomous/competent/related)	Employees can work much more autonomously through the assisted workplace than they could at conventional manual workplaces because technical aids support them.	The identity could be increased by the employee passing on his experience as a testimonial to new employees as part of the system introduction and roll-out.
wellbeing	Currently, the system design does not allow human interaction between operators and supervisors as the worker receives all information at the workplace. The system already allows the interaction with the robot/system by gesture control.	A redesign should foresee a possibility to allow human interaction with other people (e.g. using headsets for communication). Further, a possibility to interact with the robot/system by voice control could be integrated.
justice and dignity (privacy/freedom of surveillance)	Through robot assistance, the system enables human beings with different levels of competence to work on the workstation.	In a redesign, the system should be equipped with an ergonomic worktable, electric motors for adjusting the height of the table, and a projection system to visualise worker instructions on the

		worktable. This would increase the inclusivity of disabled persons.
	In the current design, the worker is monitored by a camera system, which records each operator's movement, creating the feeling of being surveyed all the time.	The system design needs to be introduced to the worker explaining that the data from the camera system is not used to measure the individual and by a transparent visualisation of data (worker can see the same data and dashboards as supervisors).

6. Discussion and limitations of the proposed approach

As the current work presented in this paper does not yet provide a practical example or a case study application in which the proposed method of VSD was strictly applied, there are some underlying limitations and implications to academia and industrial practice. In order to reach a fully human-centred, ethically designed workplace the design process needs to be conducted according to the principles of VSD right from the beginning and with the necessary interconnections and recursions between the three parts of VSD. For this, the responsible work place designers, engineers and planers in an industrial environment need to have profound competences in the field of VSD.

For academia, this paper provides a novel contribution to the existing body of knowledge in the context of workplace design and VSD as there has been identified a lack in scientific methods for including human values in addition to traditional objectives related to profit and productivity. Therefore, it motivates further research in this field.

7. Conclusions

This work points out a common problem in engineering design. Many system designers focus primarily on functional requirements based on traditional design methods without making an explicit orientation towards critical human values, particularly those of moral significance. This paper presents how an AI-assisted assembly workstation designed using conventional design methods can be scrutinised and ameliorated utilising Value Sensitive Design. The empirical analysis summarised the main functional requirements of all relevant stakeholders. In the subsequent conceptual investigation, the rarely considered values were focused on, and working definitions were constructed. In the subsequent technical investigation, optimisation measures were derived that will enable a more ethically oriented redesign of the assembly workplace in the future. Above all, this work is intended to encourage technicians to centralise ethical values in planning and enrich or supplement traditional methods with those of VSD. As an outlook for the future, we would like to encourage other scholars to do research in this direction and validate the applicability and effectiveness of such an approach by employing the method in other, more detailed case studies.

Acknowledgements

The authors thank the German Federal Ministry for Economic Affairs and Energy (BMWi) for its financial and organizational support of the "Mittelstand 4.0-Kompetenzzentrum Augsburg" [Grant no. 01MF16002B].

References

[1] Umbrello Steven. (2020) "Meaningful Human Control Over Smart Home Systems" *HUMANA.MENTE Journal of Philosophical Studies* **13** (**37**): 40–65.

[2] Roth Elisa, Moncks Mirco, Bohne Thomas, Pumplun Luisa (2020) "Context-Aware Cyber-Physical Assistance Systems in Industrial Systems: A Human Activity Recognition Approach. In: Fortino Giancarlo(eds) *Proceedings of the 2020 IEEE International Conference on Human-Machine Systems (ICHMS): Sept 7-9, 2020, Rome, Italy*, [Piscataway, New Jersey], IEEE.

[3] Mark Benedikt G., Hofmayer Sarah, Rauch Erwin, Matt Dominik T. (2019) "Inclusion of Workers with Disabilities in Production 4.0: Legal Foundations in Europe and Potentials Through Worker Assistance Systems" *Sustainability* **11** (**21**).

[4] Zolotová Iveta, Papcun Peter, Kajáti Erik, Miškuf Martin, Mocnej Jozef. (2020) "Smart and cognitive solutions

for Operator 4.0: Laboratory H-CPPS case studies" *Computers & Industrial Engineering* **139**.
[5] Romero David, Bernus Peter, Noran Ovidiu, Stahre Johan, Fast-Berglund Åsa (2016) "The Operator 4.0: Human Cyber-Physical Systems & Adaptive Automation Towards Human-Automation Symbiosis Work Systems. In: Nääs Irenilza A., Vendrametto Oduvaldo, Mendes Reis João, Gonçalves Rodrigo F., Terra Silva Márcia and Cieminski Gregor von, et al.(eds) *Advances in production management systems: Initiatives for a sustainable world IFIP WG 5.7 International Conference, APMS 2016*, Cham, Springer.
[6] Gazzaneo Lucia, Padovano Antonio, Umbrello Steven. (2020) "Designing Smart Operator 4.0 for Human Values: A Value Sensitive Design Approach" *Procedia Manufacturing* **42**: 219–26.
[7] Taylor Mark P., Boxall Peter, Chen John J.J., Xu Xun, Liew Angela, Adeniji Adebayo. (2020) "Operator 4.0 or Maker 1.0? Exploring the implications of Industrie 4.0 for innovation, safety and quality of work in small economies and enterprises" *Computers & Industrial Engineering* **139**.
[8] Vernim Susanne, Krauel Moritz, Reinhart Gunther. (2021) "Identification of digitalization trends and use cases in assembly" *Procedia CIRP* (**97**): 136-141.
[9] Koch Paul J., van Amstel Marike K., Dębska Patrycja, Thormann Moritz A., Tetzlaff Adrian J., Bøgh Simon, et al. (2017) "A Skill-based Robot Co-worker for Industrial Maintenance Tasks" *Procedia Manufacturing* **11**: 83–90.
[10] Longo Francesco, Padovano Antonio, Umbrello Steven. (2020) "Value-Oriented and Ethical Technology Engineering in Industry 5.0: A Human-Centric Perspective for the Design of the Factory of the Future" *Applied Sciences* **10** (**12**).
[11] Winner Langdon (2004) "Do artifacts have politics? In: Kaplan David M.(eds) *Readings in the philosophy of technology*, Lanham, Rowman & Littlefield.
[12] Rauch Erwin, Spena Pasquale R., Matt Dominik T. (2019) "Axiomatic design guidelines for the design of flexible and agile manufacturing and assembly systems for SMEs" *International Journal on Interactive Design and Manufacturing (IJIDeM)* **13** (**1**): 1–22.
[13] Kovács Ilona, Moniz António. (1994) "Trends for the development of anthropocentric production systems in small less industrialised countries: The case of Portugal" *Proceedings of European Workshop in Human Centred Systems*: 1–20.
[14] Rauch Erwin, Linder Christian, Dallasega Patrick. (2020) "Anthropocentric perspective of production before and within Industry 4.0" *Computers & Industrial Engineering* **139**.
[15] Chuang Shan-Ping, Yang Chang-Lin. (2014) "Key success factors when implementing a green-manufacturing system" *Production Planning & Control* **25** (**11**): 923–37.
[16] Cochran David S., Rauch Erwin. (2020) "Sustainable Enterprise Design 4.0: Addressing Industry 4.0 Technologies from the Perspective of Sustainability" *Procedia Manufacturing* **51**: 1237–44.
[17] Brown Christopher A., Rauch Erwin. (2019) "Axiomatic Design for Creativity, Sustainability, and Industry 4.0" *MATEC Web Conf.* **301**.
[18] Cochran David S., Arinez Jorge F., Duda James W., Linck Joachim. (2001) "A decomposition approach for manufacturing system design" *Journal of Manufacturing Systems* **20** (**6**): 371–89.
[19] Strohm Oliver, Ulich Eberhard (1999) "Ganzheitliche Betriebsanalyse unter Berücksichtigung von Mensch, Technik und Organisation (MTO-Analyse). In: Dunckel Heiner(eds) *Handbuch psychologischer Arbeitsanalyseverfahren*, Zürich, vdf Hochschulverlag AG an der ETH Zürich.
[20] Rocha Carlos A. P., Rauch Erwin, Vaimel Taavi, Garcia Manuel A. R., Vidoni Renato. (2021) "Implementation of a Vision-Based Worker Assistance System in Assembly: a Case Study" *Procedia CIRP* **96**: 295–300.
[21] Winkler Till, Spiekermann Sarah. (2021) "Twenty years of value sensitive design: a review of methodological practices in VSD projects" *Ethics and Information Technology* **23** (**1**): 17–21.
[22] Friedman Batya, Hendry David (2019) "Value sensitive design: Shaping technology with moral imagination, Cambridge Massachusetts, London England, The MIT Press.
[23] Friedman Batya, Kahn Peter, Hagman Jennifer, Severson Rachel, Gill Brian. (2006) "The Watcher and the Watched: Social Judgments About Privacy in a Public Place" *Human-Computer Interaction* **21** (**2**): 235–72.
[24] Nathan Lisa P., Friedman Batya, Klasnja Predrag, Kane Shaun K., Miller Jessica K. (2008) "Envisioning systemic effects on persons and society throughout interactive system design. In: Marsden Gary(eds) *Proceedings of the 7th ACM Conference on Designing Interactive Systems*, New York, NY, ACM.
[25] Czeskis Alexei, Dermendjieva Ivayla, Yapit Hussein, Borning Alan, Friedman Batya, Gill Brian, et al. (2010) "Parenting from the pocket. In: Cranor Lorrie F.(eds) *Proceedings of the Sixth Symposium on Usable Privacy*

and Security, New York, NY, ACM.

[26]Watkins Kari E., Ferris Brian, Malinovskiy Yegor, Borning Alan (2013) "Beyond Context-Sensitive Solutions: Using Value-Sensitive Design to Identify Needed Transit Information Tools. In: Jones Steven L.(eds) *Urban public transportation systems 2013: Proceedings of the third International Conference on Urban Public Transportation Systems*, Reston, Va, American Society of Civil Engineers.

[27]Yoo Daisy. (2021) "Stakeholder Tokens: a constructive method for value sensitive design stakeholder analysis" *Ethics and Information Technology* **23** (**1**): 63–7.

[28]Friedman Batya, Hurley David, Howe David C., Felten Edward, Nissenbaum Helen (2002) "Users' conceptions of web security: a comparative study. In: Terveen Loren(eds) *CHI '02 Extended Abstracts on Human Factors in Computing Systems*, New York, NY, ACM.

[29]Woelfer Jill P., Iverson Amy, Hendry David G., Friedman Batya, Gill Brian T. (2011) "Improving the safety of homeless young people with mobile phones: values, form and function. In: Tan Desney, Fitzpatrick Geraldine, Gutwin Carl, Begole Bo and Kellogg Wendy A.(eds) *Conference proceedings and extended abstracts / the 29th Annual CHI Conference on Human Factors in Computing Systems*, New York, NY, ACM.

[30]Friedman Batya. (1997) "Social Judgments and technological innovation: Adolescents' understanding of property, privacy, and electronic information" *Computers in Human Behavior* **13** (**3**): 327–51.

[31]Borning Alan, Friedman Batya, Davis Janet, Lin Peyina (2005) "Informing Public Deliberation: Value Sensitive Design of Indicators for a Large-Scale Urban Simulation. In: Gellersen Hans, Beaudouin-Lafon Michel, Mackay Wendy and Schmidt Kjeld(eds) *ECSCW 2005: Proceedings of the Ninth European Conference on Computer-Supported Cooperative Work, 18-22 September 2005, Paris, France*, Dordrecht, Springer.

[32]Freier Nathan G. (2008) "Children attribute moral standing to a personified agent. In: Burnett Margaret(eds) *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: Conference proceedings ; April 5-10, 2008 in Florence, Italy*, New York, NY, ACM.

[33]Munson Sean A., Avrahami Daniel, Consolvo Sunny, Fogarty James, Friedman Batya, Smith Ian (2011) "Attitudes toward online availability of US public records. In: Bertot John(eds) *Proceedings of the 12th Annual International Digital Government Research Conference Digital Government Innovation in Challenging Times*, New York, NY, ACM.

[34]Miller Jessica K., Friedman Batya, Jancke Gavin (2007) "Value tensions in design: the value sensitive design, development, and appropriation of a corporation's groupware system. In: Gross Tom(eds) *Proceedings of the 2007 International ACM Conference on Supporting group work*, New York, NY, ACM.

[35]Denning Tamara, Borning Alan, Friedman Batya, Gill Brian T., Kohno Tadayoshi, Maisel William H. (2010) "Patients, pacemakers, and implantable defibrillators: human values and security for wireless implantable medical devices. In: Mynatt Elizabeth, Schoner Don, Fitzpatrick Geraldine, Hudson Scott, Edwards Keith and Rodden Tom(eds) *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, New York, NY, ACM.

[36]Yoo Daisy, Huldtgren Alina, Woelfer Jill P., Hendry David G., Friedman Batya (2013) "A value sensitive action-reflection model: evolving a co-design space with stakeholder and designer prompts. In: Mackay Wendy E., Brewster Stephen and Bødker Susanne(eds) *CHI 2013 Conference on Human Factors in Computing Systems, conference proceedings*, New York, NY, ACM.

[37]Vernim Susanne (2020) "Anforderungsermittlung für das Montagepersonal in der digitalen Transformation" Dissertation, Garching.

[38]Honneth Axel (2018) "Kampf um Anerkennung: Zur moralischen Grammatik sozialer Konflikte, Frankfurt am Main, Suhrkamp.

[39]Breen Keith (2019) "Meaningful Work and Freedom: Self-Realization, Autonomy, and Non-Domination in Work. In: Yeoman Ruth, Bailey Catherine, Madden Adrian and Thompson Marc(eds) *The Oxford handbook of meaningful work*, Oxford, Oxford University Press.

[40]Bailey Catherine, Madden Adrian. (2016) "What Makes Work Meaningful - Or Meaningless" *MIT Sloan Management Review* **57** (**4**): 53–61.

[41]Sheldon K. M., Elliot A. J., Kim Y., Kasser T. (2001) "What is satisfying about satisfying events? Testing 10 candidate psychological needs" *J Pers Soc Psychol* **80** (**2**): 325–39.

[42]Umbrello Steven, van de Poel Ibo. (2021) "Mapping value sensitive design onto AI for social good principles" *AI Ethics* **1** (**1**).

[43]Foucault Michel (1977) "Discipline and punish: The birth of the prison, London, Pinguin Books Ltd.

[44]Bernstein Ethan. (2014) "How Being Filmed Changes Employee Behavior. Available at: https://hbr.org/2014/09/how-being-filmed-changes-employee-behavior.
[45]Marmot Michael (2005) "The status syndrome: How your social standing affects our health and longevity, New York, NY, Holt.