Involving Users in the Development of AI-Supported CAM Systems by Co-Creation Methods

Nina Rußkamp, Lorena Niebuhr, and Eva-Maria Jakobs
Human-Computer Interaction Center / Text Linguistics and Technical Communication
RWTH Aachen University
Aachen, Germany
email: {n.russkamp, l.niebuhr, e.m.jakobs}@tk.rwth-aachen.de

***Abstract*—In many German key industries, the process planning for manufacturing workpieces is carried out with Computer-Aided Manufacturing (CAM) systems. Shorter innovation cycles and greater product customization in the industry 4.0 era are rapidly increasing the complexity of products and CAM systems, making it even for experienced CAM planners challenging to carry out their work on time. This is also because CAM systems are still difficult to use and learn. The research and development project CAM2030 aims to partially automate parameter optimization in the CAM-planning process with the help of artificial intelligence, cloud computing, and evolutionary algorithms. The aim is to save time, get closer to the perfect process planning, and relieve the user. An interdisciplinary team of experts from industry and academia is developing approaches for a new generation of CAM systems. This paper focuses on how co-creation facilitates the involvement of software users in developing new software generations that integrate new technologies, such as artificial intelligence. A methodological co-creation framework was developed to continuously incorporate the actors involved in the innovation process. The framework was applied to the project case study to investigate (i) the potential of the co-creation framework for eliciting user expectations relevant to acceptance and usability, and (ii) what retraining needs the integration of artificial intelligence requires and how users could be supported when switching to the new system. The co-creation approach shows a high potential to integrate the user's (CAM planner's) perspective in interdisciplinary innovation processes. It facilitated the identification of general and selective relearning needs induced by redesigning CAM-planning processes, the system (interface), and the integration of novel technologies. Applying this knowledge to the design and implementation of new software generations benefits the users and companies; it makes the system introduction easier, faster, and less prone to disruptions. Future research should provide guidance for introducing new generations of CAM software and accompanying the transformation process.**

Keywords- user perspective; co-creation; computer-aided-manufacturing; artificial intelligence; software training.

I. INTRODUCTION

In the manufacturing industry, transformation towards shorter innovation cycles and greater product customization increases the complexity of Computer-Aided Manufacturing (CAM) tasks and systems. CAM planners face the challenge of meeting rising quality requirements under time pressure. CAM planners usually achieve a process planning quality close to the optimum within a few hours (80 % solution). Most of their working time is spent on parameter adjustments to identify and eliminate minor but technically relevant errors. A basic assumption is that enriching software systems with novel technologies, especially Artificial Intelligence (AI), can reduce the users' workload [1].

In the research and development project CAM2030, an interdisciplinary team of experts from industry and academia is developing approaches for a new generation of CAM systems that integrate technologies, such as artificial intelligence, cloud computing, and evolutionary algorithms. The innovation process focuses on partially automating CAM-planning processes, especially CAM parameterization. The automation requires a modification of the parameterization process which will also lead to changes in the working processes of CAM planners. Thus, AI integration raises the challenges of finding out where CAM planners need to rethink and relearn working routines, which solutions are acceptable and comprehensible to users, and what support they need to adapt to changing workflows as efficiently as possible.

An essential prerequisite for achieving the project goal is to bring actor-specific perspectives together, close knowledge gaps, and integrate user perspectives [1]. This paper focuses on the involvement of CAM users in the innovation process. Therefore, a methodological co-creation framework was developed that systematically incorporates the actors involved in the innovation process [2][3]. The co-creation framework is intended to support the development process in and across different innovation stages. Selected co-creation methods were adapted and combined for collaboration in online workshops under remote conditions. The approach was tested and evaluated guided by the following research questions (RQ):

RQ1: Does the co-creation approach provide early indications of acceptance-relevant user expectations and requirements for the new system generation (criterion: acceptance and usability)?

RQ2: Does the co-creation approach enable early indications of potential support needs and suitable measures to cover them? Where do users need support and explanations when switching to the new system (e.g., in the interface design or by training)? How should new routines, interfaces, and knowledge requirements be introduced? How high is the retraining requirement?

Section II presents related work on developing AI-supported systems for the manufacturing industry. The methodological approach of this study, developing and implementing the co-creation framework, is described in Section III. The results of the study are presented in Section IV. Section V concludes the findings and provides an outlook for future research. Finally, the limitations of the study are outlined in Section VI.

II. Related Work

In this section, the state of the art is shortly summarized with respect to two foci: requirements for AI-supported systems and their use in the manufacturing industry (Subsection A) and co-creation approaches for product and process innovation (Subsection B).

A. Requirements for AI-Supported Systems and Their Use in the Manufacturing Industry

When AI technologies are introduced in the context of the manufacturing industry, they face a unique set of challenges compared to their general use [4]. Introducing technologies into production environments involves considering existing facilities, IT systems, and the employees who run that production. Therefore, requirements for integrating AI technologies can be derived from general requirements but must be adapted to the area of application [4]. Few publications address requirements for AI technologies in a production environment [4][5].

Hoffmann et al. [4] introduce 16 requirements divided into five categories: Adaptation, Engineering, Embedding, Security, and Trust, that need to be considered when introducing AI technologies in a production environment.

Adaption: When introducing AI technologies, they should be adapted to the existing production environment. The introduction should be gradual, firstly keeping the human employee in control of all decisions, serving as a decision support system. In addition, the availability of the data needed by the AI has to be considered, and potential conflicts in terms of legal, cultural, technical, and security issues have to be clarified.

Engineering: Keeping the AI system as simple as possible is a primary goal when designing the AI system. The complexity of the system should be hidden. The user of the AI-based system most likely doesn't have a background in computer science. The simplicity of the design contributes to the robustness of the system. The AI system should be able to physically and virtually learn and incrementally adapt to the production environment [4].

Embedding: When embedding AI technologies, a trust space and boundary need to be defined, such as a checkpoint for the human employee to prove the plausibility of the AI's decisions. AI knowledge should be distributed to other AIs via higher-level systems or communication networks. However, the AI should not base its conclusions on data created by another AI [4].

Safety: The safety and security of AI technologies are a very broad area for research and requirements engineering. It is important to ensure that production systems are safe in accordance with applicable laws and regulations and do not pose a risk to human employees, even in the case of self-improvement. The risk for failure should be transparent. Industrial AI must be robust against random and deliberate adversary input [4].

Trust: Trust contributes to security and performance; it is an important factor for acceptance [5]. To support trust, the AI system's decisions should be as transparent and understandable as possible. The system should be able to explain its decision, e.g., through visualizations [6]. Any errors in the AI's assumptions should be detectable and correctable. Levels of trust or levels of quality should be used to express the probability of failure [4]. The AI's capabilities should be provable in a test run or a virtual environment. AI systems in the manufacturing industry need to be free of bias in treating all vendors' equipment equally. A measure of confidence should be made when giving action recommendations. AI systems are expected to have a 100 % solution rate, which cannot be achieved by a technical system [4]. The level of uncertainty should therefore be communicated to the user [5].

Both the system and the user require an effective learning process. While the system needs time to learn the user's behavioral patterns, intentions, and operational status, users need adequate training with the system [5].

A critical challenge is establishing a skilled workforce for the future manufacturing industry [7]. However, it is rarely discussed how to cover CAM users' relearning needs resulting from the integration of AI-based features. Jiao et al. [7] postulate to meet digitalization-related challenges by fostering nontechnical skills, such as continuous learning, communication, critical thinking, and making decisions using incomplete knowledge. To our knowledge, guidelines for the design of AI-sensitive training formats are still missing.

B. User Integration: Co-Creation Approaches for Product and Process Innovation

To date, software engineering methods tailored to developing AI-based systems are scarce [8]. Existing approaches focus more on identifying system-immanent challenges than user needs [2]. One approach to actively involve users throughout the whole innovation process is co-creation. Despite its high potential, the use of co-creation methods for the user-centered innovation of complex software systems for the manufacturing industry is hardly discussed (but, e.g., [7][8]).

The key element of co-creation is the collaboration between software production- and application-related actors as part of "an active, creative and social process" [11]. The process facilitates reducing uncertainties by providing access to two types of information: customer and market needs, e.g., users' motives and preferences for new products and services *(need information)* and possibilities for their (technological) implementation *(solution information)*. The co-creation typology proposed by [11] classifies co-creation methods based on three dimensions:

The stage in the innovation process: It refers to the point in time when the method is applied to the innovation process. *Front-end* co-creation at the early stages of the innovation process mainly focuses on conceptual tasks, i.e., idea generation and selection. In contrast, *back-end* co-creation deals with the design and testing of a product at later innovation stages.

The degree of collaboration: It is determined by the number of collaborating partners and the company-to-customer ratio (developer-to-user ratio), e.g., 1:n or n:m.

The degrees of freedom: They determine the customer's autonomy in the innovation process resulting from the type of task (open vs. predefined task).

Due to the Covid-19 pandemic, research on virtual co-creation methods has increased (e.g., [12]).

III. METHODOLOGY

The methodology comprises three subsections: a description of the innovation process segmented into five innovation stages the co-creation framework is based on (Subsection A), development of the framework and the methodological design of the single stages in general (Subsection B), and detailed insights into the procedure of selected stages (Subsection C).

A. Overview of the Co-Creation-Based Framework

The co-creation-based framework was abstracted from the innovation process in the project CAM2030 between 2020 and 2023. It covers five innovation stages, from eliciting the as-is condition of the CAM-planning process to introducing next-generation CAM systems (see Fig. 1).

Stage i aimed at creating a shared understanding of the status quo and, based on this, at deriving requirements for its partial automation. The first step was to elicit, model, and visualize the CAM-planning process and its embedment in the higher-level production process as currently conducted in the manufacturing industry. In the second step, the resulting process models were used to identify weak points and automation potential of CAM-planning processes and their implications for the design of

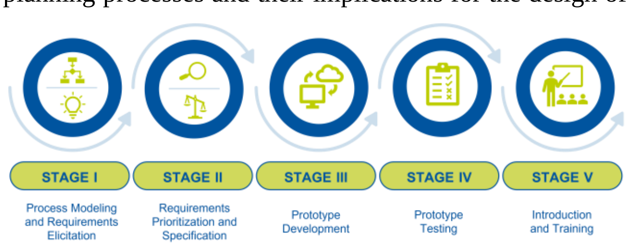

Figure 1. Innovation stages for developing AI-supported CAM systems using co-creation.

next-generation CAM systems. The results comprised improved and enriched process models [13], a ranked list of role-related, topically clustered no-go measurements, and, inverted and complemented, a structured catalog of requirements for the design of CAM systems.

Based on stage i, stage ii served the prioritization, specification, and complement of requirements, mainly focusing on the user interface redesign for optimizing CAM parameter settings. The outcome was a prioritized and categorized list of requirements for CAM systems in general and the user interface in particular.

Stage iii marked the transition from conceptualization to implementation. The focus was on consolidating knowledge about system design requirements and developing a typical user path, a mockup for the future CAM-planning process, and an interactive prototype for the user interface.

Stage iv was iteratively conducted with prototypes of different maturity levels. The prototypes were evaluated with regard to weaknesses and potential for optimization. In addition to guidelines for improving the prototype, user feedback regarding integrated help functions and training was gathered.

Stage v (not yet fully implemented) is supposed to yield a requirements profile for introducing next-generation CAM systems and further training of CAM planners. The profile should consider different categories, such as the content and format of training and the planner's expertise.

B. Stage-Wise Development of the Framework

For each stage, a methodological approach was developed, implemented, and evaluated, inter alia [14]. The approaches were mainly based on co-creation, partly complemented by other formats, e.g., online surveys. Co-creation was applied in online workshops involving developers, CAM users, human-centered work design experts, and technical communication experts. The workshops were moderated by a team of workshop leaders who accompanied the participants to work together on system development tasks. The CAM planners were asked to provide input and/or evaluate possible solutions in all innovation stages. Each workshop ended with an evaluation of the methods used in the workshop. The co-creation workshop tasks varied in several aspects:

- the group size (single-work tasks vs. group tasks in separated teams or the plenum)
- the group composition (role-related teams vs. interdisciplinary teams),
- the methods used (front-end vs. back-end co-creation, integration of co-creation and process modeling based on the C3 notation [15] [16])
- the tools used (selection of Zoom, Google Docs, Google Forms, Mural, Figma, and Microsoft Office). Google Docs was also used, among other things, to share organizational information, such as the workshop agenda and the list of participants. It served as a guide for the workshop procedure.

Copyright (c) IARIA, 2023. ISBN: 978-1-68558-078-0

- the synchrony of user involvement (preparatory tasks prior to the workshop vs. collaboration tasks during the workshop vs. inter-workshop tasks vs. evaluation tasks after the workshop).

The workshops were digitally recorded. The recording included video and audio data as well as written documents and visualizations created during the workshop, e.g., notes in shared text documents and online whiteboards. The audio was transcribed. The transcripts were supplemented with notes and evaluated qualitatively (content analysis). Surveys were analyzed qualitatively and quantitatively (descriptive statistics). The results were made available to all project partners. They were a prerequisite and input for the next innovation step.

C. *Methodological Design of Stages i, ii, and iv*

As this paper mainly refers to results yielded from stages i, ii, and iv, the methodological approaches of these stages are described in more detail:

The key design element of *stage i* was the combination of co-creation and process modeling methods [14]. The purpose of integrating process modeling was tripartite: (i) to equalize differences in knowledge about the CAM-planning process, (ii) to identify and merge role-specific perspectives (e.g., general mechanical engineering vs. aircraft manufacturing), and (iii) to facilitate getting in the requirements elicitation. The elicitation, modeling, and visualization of CAM-related processes, as they are typically conducted in the manufacturing industry, took place before the co-creation workshop pictured in Fig. 2.

The workshop applied front-end co-creation (e.g., warm-up challenge as an idea generation task with high degrees of freedom). Group sizes and compositions were varied task-by-task while a shared text document was accessible for all participants throughout the workshop serving as results log.

For the co-creation workshop in *stage ii*, the digital whiteboard tool Mural was used to enable the workshop participants to capture all workshop results – topically clustered requirements and their prioritization – at once. Dot voting was used to prioritize requirements and identify the need for requirements specification (see Fig. 3).

Stage iv was divided into three parts: (i) a preliminary survey with CAM users, (ii) a co-creation test workshop, and (iii) a complementary prototype evaluation (see Fig. 4). To get multiple feedback, especially from CAM planners, the approach alternates synchronous (part ii) and asynchronous (parts i and iii) formats. This enabled the discussion of the pre-survey results during the workshop and the prototype evaluation to take place either during or after the workshop. Different tools, e.g., Figma and Google Forms, were combined for the prototype evaluation. Figma allowed self-experience with the interactive prototype; the questionnaire was created in Google Forms.

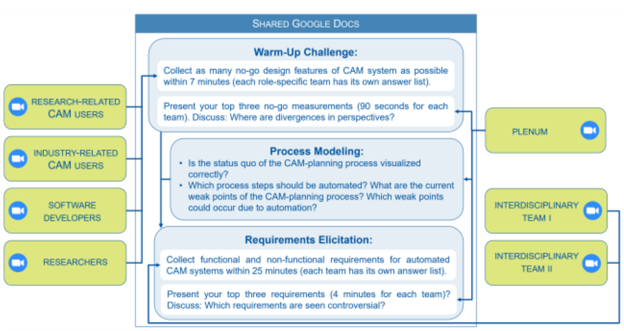

Figure 2. Co-creation workshop (stage i).

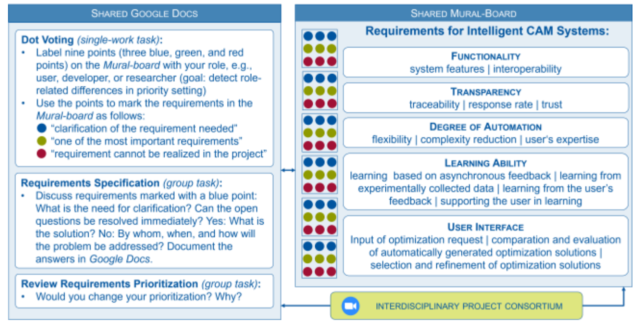

Figure 3. Co-creation workshop (stage ii).

IV. Results and Discussion

The approach shows a high potential to support all stakeholders in creating a shared understanding of the innovation process and the resulting CAM system. The co-creation workshops helped to identify and reconcile diverging perspectives (Subsection A). The user input was very productive: It provided the need for the redesign of the overall system and the user interface and, as a result, the need for relearning working routines (Subsection B). Additionally, it gave valuable hints for the design of integrated help functions and software training (Subsection C).

A. *Role-Specific Perspectives on AI Integration*

From the perspective of manufacturing companies, one risk is that workers will perceive automation as unnecessary, arguing that it is too complex and offers too little benefit compared to the current process. High training requirements and costs associated with the lack of intuitive operation of partially automated CAM systems are rejected. AI-based CAM systems must be practical and

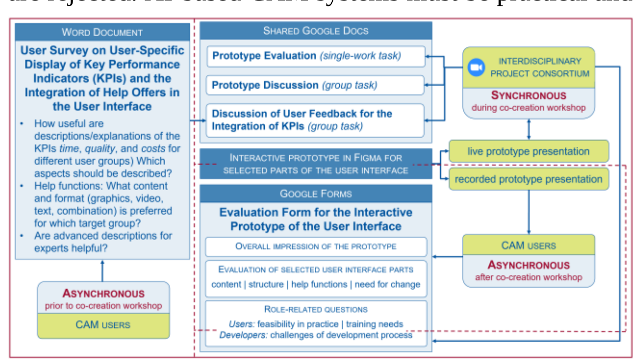

Figure 4. Structure of the prototype testing (stage iv).

appropriate for the application domain.

Developers, especially artificial intelligence experts, consider intransparency, i.e., lacking traceability of automated decisions made, as one of the three most significant inhibitors to the acceptance by CAM planners (see also [4]). A related issue is the unpredictability of the system's runtime for automated tasks and the automatically generated results' quality. The developers believe that making the system more transparent and giving the user continuous feedback on the system's current state will increase acceptance among CAM planners (see also [5]). Another barrier to acceptance, which can be exacerbated by the factors mentioned above, is the disenfranchisement of the CAM planner.

CAM planners see the risk that automation will reduce their freedom of action. They emphasize the need to balance simplifying the CAM-planning process against limiting the user's flexibility. This is coupled with the requirement for the system to adapt to the user's expertise. In addition, the lack of trustworthiness of the CAM system is considered a no-go characteristic.

Overall, the workshop participants' perspectives on tipping points for the acceptability and comprehensibility of automated CAM features gradually differ. The participants agree that the decision-making authority of the user is a prerequisite for acceptance. They emphasize the need for automation on demand.

B. Redesign and Relearning Needs

Stage iv has shown that automating the CAM parameterization has multiple consequences. It affects the workflow, the significance of Key Performance Indicators (KPIs) for the workflow, the system interface design, and the requirements for the user. The new workflow comprises three steps: (i) configuration of the CAM parameterization request (user task), (ii) execution of the optimization resulting in a set of high-quality parameter settings (automatically generated by the system), and (iii) evaluation, selection, and refinement of parameter settings (user task). The interface must be adapted to the new sequence of actions, e.g., by extending the interface to include input screens for selecting optimization preferences. Changes in the workflow and the interface force CAM planners working with present CAM systems to partly rethink and acquire specific knowledge. Setting evaluation and target values during step (i) requires knowledge of KPIs concerning production time, quality, and costs. The CAM planners need to develop an understanding of which KPIs are important and what effects they have. Partly, AI is seen as a black box that users cannot fully understand. To accept the system, users should have access to AI-specific knowledge so that they can trust the system, interpret AI-generated results, and customize AI-enhanced CAM features.

C. Implications for the Design of Integrated Help Functions, Introduction, and Training

In the workshops, the CAM planners gave valuable hints for the design of user support, which information users want to access in the CAM system (explanations and help functions as part of the user interface), and what should be taught in introductory and advanced training. A critical issue is introducing and representing KPIs for the automated CAM parameter optimization. The training should provide a basic understanding of the KPIs and CAM parameters, while the CAM system should provide help functions for further information.

The training should give users a basic understanding of the CAM system and its AI-enhanced features. CAM planners need to be sensitized to CAM-planning steps that require new knowledge or rethinking previous user paths and actions. A demonstration of the new optimization workflow and user interface should be part of the training. The introductory training should also explain how the CAM system technically processes an optimization request to increase the user's understanding of what data the system needs to be able to carry out an optimization task. The introduction of KPIs and CAM parameters should be restricted to explaining which target values can be optimized and how they relate to the KPIs time, quality, and costs. CAM parameters should be introduced as threshold values that limit the solution space of the AI-based optimization.

Regarding integrated help functions, there is a high demand for KPI descriptions explaining the KPIs time, quality, and costs. For each KPI, providing explanations in the user interface was rated as "very useful," "useful," or "rather useful" across all user groups (see Fig. 5).

Descriptions of the KPI *costs* are perceived as most important independently of the user's expertise. The KPI time should be explained for all user groups, particularly novices. The KPI *quality* is useful for all user groups; experts are particularly predestined to handle quality-related information.

There is a broad consensus on how to integrate KPI descriptions into the user interface. Depending on the type of the KPI, the preferred format varies: Time- and cost-related information should be displayed as graphics. For quality, the combination of video and graphics is most suitable. Occasionally, texts (for time) or a combination of text and graphics (for quality and costs) are requested.

Integrated help functions should give the CAM planners indications of what effect the single KPIs have:

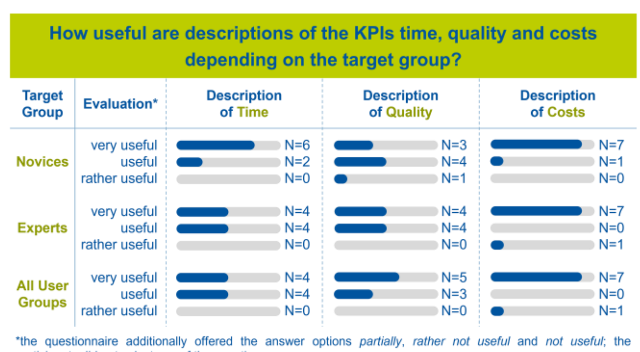

Figure 5. Ratings of the usefulness of KPI descriptions in the user interface.

Time: CAM planners should be able to calculate the processing time of their CAM plans and identify and take advantage of the potential for time reduction.

Quality: CAM planners must be able to evaluate in advance if the requested component quality can be ensured during production. Thus, they need quality estimations of, e.g., the CAM path and tools.

Costs: CAM planners need an overview of the different types of costs, e.g., machining costs, tooling costs, and personnel costs. It should be clear how changes in CAM planning affect expenses and how much the execution of the final CAM process planning costs the company.

V. CONCLUSION AND FUTURE WORK

The user's role in developing innovative software systems is often underestimated. Co-creation-based approaches are suitable means to integrate the user's perspective in interdisciplinary innovation processes. Users' involvement allows for identifying general and selective relearning needs induced by the redesign of working processes and the system. Applying this knowledge to the design and implementation of new software generations benefits the users and companies; it makes the system introduction easier, faster, and less prone to disruptions. Future research should further investigate how to introduce new generations of CAM software and accompany the transformation process.

VI. LIMITATIONS

Limitations arise from the end users' reluctance to advance research at the expense of the daily business. Other limiting factors concern the restriction of automation to one selected CAM-planning step (the CAM parameterization) in one specific CAM system and the application context (well-educated CAM planners in German SMEs).

ACKNOWLEDGMENT

This research and development project is funded by the German Federal Ministry of Education and Research (BMBF) within the "Innovations for Tomorrow's Production, Services, and Work" Program (funding number: 02J19B081) and implemented by the Project Management Agency Karlsruhe (PTKA). The authors are responsible for the content of this publication.

REFERENCES

[1] A. Csiszar, P. Hein, M. Wächter, A. Verl, and A. Bullinger, "Towards a user-centered development process of machine learning applications for manufacturing domain experts," Third International Conference on Artificial Intelligence for Industries (AI4I), Irvine, CA, USA, 2020, pp. 36-39, doi: 10.1109/AI4I49448.2020.00015.

[2] N. Rußkamp, C. Digmayer, and E.-M. Jakobs, "Co-creation-based Framework for the agile Development of AI-supported CAM Systems," 14th International Conference on Applied Human Factors and Ergonomics (AHFE 2023), unpublished.

[3] H. Belani, M. Vuković, and Ž. Car, "Requirements Engineering Challenges in Building AI-Based Complex Systems," 2019 IEEE 27th International Requirements Engineering Conference Workshops (REW), 2019, pp. 252-255, doi: 10.1109/REW.2019.00051.

[4] M. Hoffmann, R. Drath, and C. Ganz "Proposal for requirements on industrial AI solutions," in Machine Learning for Cyber Physical Systems: Selected papers from the International Conference ML4CPS 2020, J. Beyerer, A. Maier, and O. Niggemann, Eds. Berlin: Springer Vieweg, pp. 63-72, 2021, doi: 10.1007/978-3-662-62746-4.

[5] S. Pütz et al., "An Interdisciplinary View on Humane Interfaces for Digital Shadows in the Internet of Production," 15th International Conference on Human System Interaction (HSI), 2022, pp. 1-8, doi: 10.1109/HSI55341.2022.9869467.

[6] L. Tonejca, G. Mauthner, T. Trautner, V. König, and W. Liemberger, "AI-Based Surface Roughness Prediction Model for Automated CAM-Planning Optimization," 2022 IEEE 27th International Conference on Emerging Technologies and Factory Automation (ETFA), 2022, pp. 1-4, doi: 10.1109/ETFA52439.2022.9921281.

[7] R. Jiao et al., "Design Engineering in the Age of Industry 4.0," Journal of Mechanical Design, vol. 143, 070801, July 2021, doi: 10.1115/1.4051041.

[8] S. Martínez-Fernández et al., "Software Engineering for AI-Based Systems: A Survey," ACM Transactions on Software Engineering and Methodology, vol. 31, pp. 1-59, 2022, doi:10.1145/3487043.

[9] M. Tandi and E.-M. Jakobs "Two Heads are Better than One: Co-Creation as a Resource for User Interface Design of CAx Systems," 2019 IEEE International Professional Communication Conference (ProComm), 2019, pp. 71-78, doi: 10.1109/ProComm.2019.00019.

[10] M. Oliveira, A. Bettoni, E. Coscia, and H. Torvatn "Applying Co-creation Principles to Requirement Elicitation in Manufacturing," in: HCI International 2019 – Late Breaking Papers, HCII 2019, Lecture Notes in Computer Science, vol 11786, C. Stephanidis, Ed. Cham: Springer, pp. 54-61, 2019, doi: 10.1007/978-3-030-30033-3_5.

[11] F. T. Piller, C. Ihl, and A. Vossen, "A typology of customer co-creation in the innovation process," SSRN Electronic Journal, vol. 4, Dec. 2010, doi: 10.2139/ssrn.1732127.

[12] T. Benson et al. "Virtual Co-Creation: A Guide to Conducting Online Co-Creation Workshops," International Journal of Qualitative Methods, vol. 20, 2021, doi: 10.1177/16094069211053097.

[13] F. Burgert, M. Schirmer, M. Harlacher, V. Nitsch, and S. Mütze-Niewöhner, Participative elicitation and modeling of a CAM planning process for the manufacturing of complex components using the K3 notation. Aachen: Institute of Industrial Engineering and Ergonomics, 2022, doi:10.18154/RWTH-2022-01188.

[14] N. Rußkamp et al., "New ways to design next-generation CAM systems. An integrated approach of co-creation and process modeling," in: Human Aspects of Advanced Manufacturing. AHFE (2022) International Conference. AHFE Open Access, vol 66, W. Karwowski and S. Trzcielinski, Eds. USA: AHFE International, 2022, pp. 1-12, doi: 10.54941/ahfe1002682.

[15] S. Killich et al., "Task modeling for cooperative work," Behaviour & Information Technology, vol. 18, pp. 325-338, 1999, doi: 10.1080/014492999118913.

[16] A. Nielen, Systematik für die leistungs- und zuverlässigkeitsorientierte Modellierung von Arbeits-prozessen mit kontrollflussorientierten Notationssystemen. Aachen: Shaker, 2014.