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A Vision Towards Generated Assistive Systems for Supporting Human Interactions in Production

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Abstract: Human workers need to cope with complex production settings when handling and monitoring cyber-physical production systems. Assistive systems can provide situational step-by-step support for human behavior, e.g., when interacting with a machine or for manual assembly. These systems need to take personal knowledge, workers skills or personal restrictions into account and are therefore subject to privacy concerns. However, the engineering of such interactive assistive systems within the production domain is a complex task as they might support critical functionality in dangerous environments and have a high need for safety and privacy considerations due to processing personal data. We want to investigate how the software engineering process of assistive systems in production can be improved to achieve higher reusability. Current research focuses on specific use cases and implements systems specifically for those needs without reusability in mind. We suggest using behavior and context models in a generative approach, to create a reusable method to engineer assistive systems for production environments, either as own applications or as services integrated within digital twins. We have already applied model-driven methods for assistive systems in the smart home domain and discuss the opportunities and challenges of an application of these methods for the production domain. These methods can facilitate the engineering of assistive functionalities within applications in production while meeting privacy, adaptability, and context-sensitivity requirements.

Keywords: Assistive Systems; Production; Human Support; Digital Twin; Process Models; Model-Driven Software Engineering

1 Novel Directions Talk

Motivation. The need for assistive systems in manufacturing grows due to a high complexity of tasks [LL12] and a large variety of products, production systems and tools [Fa22] resulting from mass customization. The engineering of interactive assistive systems within the production domain is challenging as they might support critical functionality in dangerous environments and have a high need for safety and privacy considerations due to the processing of personal data about human behavior. In research, current approaches assist employees on the shop floor [Ul16], use AR to assist manufacturing tasks such as assembly guidance or the inspection and evaluation of the machining processes before performing real machining [NO13], or use process models to visualize instructions for service operations [UFH19]. Current development approaches for assistive systems supporting human interactions (1) suggest mainly hand-written systems or (2) are not generalizable. The systems and graphical user interfaces must be newly developed for every use case.

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Other model-based development approaches support only certain use cases and are not generalizable.

Research question. Thus, we want to investigate *how the software engineering process of assistive systems in production can be improved to achieve a higher reusability*. We believe that the use of behavior and context models in a generative approach is a purposeful method to realize the engineering of reusable assistive systems for production environments, either as standalone applications or as services integrated into digital twins.

Assistive Systems. There are three main aspects that constitute an assistive system [Hö19]: (1) They provide situational support for human behavior, which requires them to be knowledgeable about situations and adaptable. (2) The support is based on information from previously stored and real-time monitored structural context and behavior data, which requires comprehensive models about the context as well as human behavior models. Moreover, they need monitoring capabilities to update the current status in processes and environment models. (3) They provide support at the moment a person needs it or asks for it, which requires intelligent support detection and interactive components.

Generated Assistive Systems for Smart Homes. We are successfully using the generator framework MontiGem [Ge20] to create assistive systems for smart homes supporting, e.g., cooking processes. Process and context models allow us to generate web-based multi-modal user interfaces that compose supporting texts from model information and provide pictures and audio support. We cover concepts for leading users to find or place objects using spatial relationships and object nesting.

The Need for Generated Assistive Systems in Production. These solutions can be transferred to other domains. Through our insights into production within the Cluster of Excellence "Internet of Production"(IoP)[2], we have noticed several areas where a generative approach for the creation of assistive systems is needed and would be well applicable. A generated assistive system could replace instruction manuals [SM18] for machines, which are often outdated or missing important aspects when tools are changed for a production site. Another area is manual assembly [HRU16], where tools have their fixed place and finding them in the right order or learning changed processes can be supported by training. Moreover, assistive systems can provide ergonomic support, e.g., when using data from working posture analysis [HMB18] or when monitoring the employees' mental workload [Pü22].

Challenges. When transferring model-based and generative concepts for the engineering of assistive systems to the production domain, we face several challenges.

- *High amount of relevant contextual information*: The meta-model for context information can be defined on an abstraction level which allows to reuse it for different use cases and domains [MS17]. However, the set-up of context-sensitive assistive systems is time consuming when we need to cover a high number of context objects. Methods

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such as semantic annotation of user manuals [SM18] may fasten this process but further research, e.g., on digital shadows [Be21], or using controlled natural language in domain-specific modeling languages is needed to improve the set-up.

- *High heterogeneity of user interfaces*: Assistive systems in production could exist in loud environments, users could not be able to read screens from their working position or due to their movement. Thus, generated assistive systems have to cover various multi-modal user interfaces on different devices to be reusable.
- *Adaptability to personal needs*: Assistive systems need to cover a high diversity of personal needs, e.g., human abilities, their work and learning history [UFH19], personal restrictions [Lu21], or the stress level, and to be adaptable to these needs. Specific needs [Gr21] within the production domain have to be further analyzed and we have to develop methods to incorporate these needs into models usable in the generation process of assistive systems.
- *Privacy needs*: Every assistive system needs a certain amount of personal data to be accepted by users, e.g., to be adaptable and adjustable to user preferences. Assistive systems have to consider privacy-by-design principles. Model-based approaches for privacy preservation such as [Mi19] could be incorporated into assistive systems to make sure that the data is used purposefully.

Conclusion. Model-driven software engineering can facilitate the engineering of assistive functionalities in manufacturing applications while meeting the requirements for privacy, adaptability and context sensitivity. However, there are still several challenges to overcome that raise new research questions for the model-based and model-driven software engineering of assistance systems. Moreover, we need to further explore the generalizability of a model-driven software engineering approach for the engineering of assistive systems in different use cases.

Bibliography

[Be21] Becker, Fabian; Bibow, Pascal; Dalibor, Manuela; Gannouni, Aymen; Hahn, Viviane; Hopmann, Christian; Jarke, Matthias; Koren, Istvan; Kröger, Moritz; Lipp, Johannes; Maibaum, Judith; Michael, Judith; Rumpe, Bernhard; Sapel, Patrick; Schäfer, Niklas; Schmitz, Georg J.; Schuh, Günther; Wortmann, Andreas: A Conceptual Model for Digital Shadows in Industry and its Application. In: Conceptual Modeling ER '21. Springer, 2021.

[Fa22] Fadhlillah, Hafiyyan Sayyid; Feichtinger, Kevin; Meixner, Kristof; Sonnleithner, Lisa; Rabiser, Rick; Zoitl, Alois: Towards Multidisciplinary Delta-Oriented Variability Management in Cyber-Physical Production Systems. In: 16th International Working Conference on Variability Modelling of Software-Intensive Systems. VaMoS '22. ACM, 2022.

[Ge20] Gerasimov, Arkadii; Michael, Judith; Netz, Lukas; Rumpe, Bernhard; Varga, Simon: Continuous Transition from Model-Driven Prototype to Full-Size Real-World Enterprise Information Systems. In: 25th Am. Conf. on Information Sys. (AMCIS'20). AIS, 2020.

[Gr21] Grundy, John; Khalajzadeh, Hourieh; McIntosh, Jennifer; Kanij, Tanjila; Mueller, Ingo: HumaniSE: Approaches to Achieve More Human-Centric Software Engineering. In (Ali, Raian; Kaindl, Hermann; Maciaszek, Leszek A., eds): Evaluation of Novel Approaches to Software Engineering. Springer, pp. 444–468, 2021.

[HMB18] Hellig, Tobias; Mertens, Alexander; Brandl, Christopher: The interaction effect of working postures on muscle activity and subjective discomfort during static working postures and its correlation with OWAS. International Journal of Industrial Ergonomics, 68:25–33, 2018.

[Hö19] Hölldobler, Katrin; Michael, Judith; Ringert, Jan Oliver; Rumpe, Bernhard; Wortmann, Andreas: Innovations in Model-based Software and Systems Engineering. The Journal of Object Technology, 18(1):1–60, July 2019.

[HRU16] Hinrichsen, Sven; Riediger, Daniel; Unrau, Alexander: Assistance Systems in Manual Assembly. In (Villmer, Franz-Josef; Padoano, Elio, eds): Production Engineering and Management. p. 3–14, 2016.

[LL12] Liu, Peng; Li, Zhizhong: Task complexity: A review and conceptualization framework. International Journal of Industrial Ergonomics, 42(6):553–568, 2012.

[Lu21] Luy, Calvin; Law, Jeremy; Ho, Lily; Matheson, Richard; Cai, Tracey; Madugalla, Anuradha; Grundy, John: A Toolkit for Building More Adaptable User Interfaces for Vision-Impaired Users. In: 2021 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC). 2021.

[Mi19] Michael, Judith; Netz, Lukas; Rumpe, Bernhard; Varga, Simon: Towards Privacy-Preserving IoT Systems Using Model Driven Engineering. In: MODELS 2019. Workshop MDE4IoT. CEUR Workshop Proceedings, pp. 595–614, 2019.

[MS17] Michael, Judith; Steinberger, Claudia: Context Modeling for Active Assistance. In (Cabanillas, Cristina; España, Sergio; Farshidi, Siamak, eds): Proc. of the ER Forum 2017 and the ER 2017 Demo Track co-located with the 36th Int. Conference on Conceptual Modelling (ER 2017). pp. 221–234, 2017.

[NO13] Nee, A.Y.C.; Ong, S.K.: Virtual and Augmented Reality Applications in Manufacturing. IFAC Proceedings Volumes, 46(9):15–26, 2013. 7th IFAC Conference on Manufacturing Modelling, Management, and Control.

[Pü22] Pütz, Sebastian; Rick, Vera; Mertens, Alexander; Nitsch, Verena: Using IoT devices for sensor-based monitoring of employees' mental workload: Investigating managers' expectations and concerns. Applied Ergonomics, 102:103739, 2022.

[SM18] Steinberger, Claudia; Michael, Judith: Towards Cognitive Assisted Living 3.0. In: International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops 2018). IEEE, pp. 687–692, march 2018.

[UFH19] Uhlmann, Eckart; Franke, David; Hohwieler, Eckhard: Smart Maintenance – dynamic model-based instructions for service operations. Procedia CIRP, 81:1417–1422, 2019. 52nd CIRP Conference on Manufacturing Systems (CMS).

[Ul16] Ullrich, Carsten: Rules for Adaptive Learning and Assistance on the Shop Floor. In: Int. Conf. on Cognition and Exploratory Learning in the Digital Age (CELDA). 2016.