Experiences in Collecting Requirements for an AI-enabled Industry 4.0 Platform

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Abstract

Industry 4.0 software platforms target creation, provisioning and operation of industrial applications, e.g., on a shopfloor. Recent advances in Artificial Intelligence (AI), one pillar of Industry 4.0, lead to new demands. The funded project IIP-Ecosphere designs a novel, AI-enabled Industry 4.0 platform. As a basis, we applied two complementing requirements views, namely usage and functional view inspired by IIRA, and collected 67 usage view scenarios and 141 top-level functional requirements. In this paper, we summarize our experiences on the requirements collection and discuss their effect on the yet realized platform.

1 Introduction

Intelligent manufacturing promises the increase of the productivity of technical systems and the (manufacturing) processes, e.g., through Artificial Intelligence (AI) [2]. Further trends, such as edge devices to enable low latency AI at production machines, virtualization or containerization increase both, complexity and heterogeneity of such setups. Managing heterogeneity is the aim of recent standardization efforts, e.g., OPC UA (Companion Specifications) or Asset Administration Shells (AAS). These trends lead to new requirements for Industry 4.0 software platforms, aiming at integrating machines and processes by applications.

In the BMWK funded project IIP-Ecosphere[1], more than 18 partners research new concepts for equipping industrial production processes with AI. A core activity is the creation of an AI-enabled Industry 4.0 platform to experiment with and to showcase novel solutions. As the partners act in various ecosystem roles, we performed an intensive, interactive requirements collection, which also aims at influencing future platforms after the project's lifetime. Existing work such as [3] focuses more on requirements approaches for (I)IoT platforms or selected requirements [4]. In [5], we initially discussed approaches and experiences from the beginning of IIP-Ecosphere.

In this paper, we summarize our approach to requirements collection (Section 2) and then contribute our experiences (Section 3) after mostly completing the realization of our platform.

[1] https://www.iip-ecosphere.de/

2 Requirements Collection Approach

As suggested by industrial IIP-Ecosphere partners, we based our work on the ideas of the German Standardization Roadmap Industry 4.0, which advocates the 'Industrial Internet Viewpoints' of the Industrial Internet Reference Architecture (IIRA)[2]. Starting with a 'Business View' justifying the development decision of a system, the IIRA approach suggests two requirements views, the 'Usage View' - roles, system elements and scenarios - and the 'Functional View' on the functions of the System under Consideration (SuC).

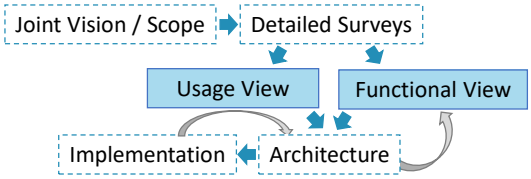

Figure 1: Requirements collection in context.

As the platform is a mandatory result defined in our Grant Agreement (GA), we deferred the creation of the business view and, as illustrated in Figure 1, started with a discussion of the *Joint Vision/Scope* of the platform among 8 partners that were responsible for or interested in the platform development. Soon the demand for a justification of the novelty of the vision came up, which we answered through *Detailed Surveys*, including a systematic review of 21 industrial platforms[3] and a form-based survey with 75 industrial participants[4]. The identified capabilities and gaps mostly justified our vision and indicated initial priorities for the requirements collection.

In parallel, two teams collected input for the usage/functional view based on interactive workshops, (form-based) interviews and document analyses. In particular, we based the *Usage View* on precursor work of LNI 4.0[5]. We used the IIRA approach as guideline to structure the workshop discussions, starting with an introduction of the usage view elements and already gained results, e.g., a diagram of the SuC,

[2] https://www.iiconsortium.org/pdf/IIRA-v1.9.pdf
[3] https://doi.org/10.5281/zenodo.4485756
[4] https://doi.org/10.5281/zenodo.6334521
[5] https://www.plattform-i40.de

roles or example scenarios. We collected the results in a Word file finally consisting of 18 entities, 19 roles, 43 edge deployment and 24 AI activities (the LNI 4.0 origin had 5 entities, 7 roles and 27 activities).

For the *Functional View*, we focused on the collection of functional and quality demands for the SuC. We recorded the identified demands as textual requirements in a Word file in terms of template sentences [1] (often with explaining text), clustered the requirements into topics, e.g., on the 'AI toolkit' of the platform, and, further, structured similar requirements into top-level and sub-requirements.

Based on our vision, the surveys and the discussions, both teams jointly decided on the prioritization of the scenarios/requirements. Besides intermediary feedback by the workshop/interview participants, the teams made the resulting documents available to the consortium and integrated feedback.

3 Experiences and Discussion

The interactive activities for the *usage view* allowed for more creativity and interaction, e.g., the participants talked much about desired system interactions or limitations. For example, initially the stakeholders aimed for a deep integration of (own) AI tools. One participant raised the point, that data analysts tend to use individual toolchains, leading to the decision that the platform shall support external AI tools but not integrate them. However, we also experienced that creating usage view scenarios is rather time consuming, so the final usage view for the platform[6] covers only two core topics: Managing distributed tasks and edge devices as well as AI integration.

The activities for the *functional view* were more focused on technical topics, e.g., how to develop applications for the platform. Here, the interaction was less lifely and the participants were mostly technical experts, probably biased by our invitation. Yet, creating the functional view revealed, e.g., the need for human approvals of automated actions such as enacting an improved (online learned) AI model.

We compared both documents and identified that they share 66% topics, but also that requirements are missing, e.g., due the different perspectives of the two views. As mitigation, we complemented the functional view[7] by topics only stated in the usage view. Finally, the functional view includes 141 top-level and 179 sub-requirements, among them 16% quality requirements, most on data frequency or volume.

We also experienced questions why certain scientific requirements are needed at all, e.g., on runtime or self-adaption capabilities. While such questions may indicate superfluous or risky functionality from a business/industrial perspective, requirements in a research project must also reflect the scientific side, i.e., they must sometimes be defended or re-prioritized against more practical/industrial requirements.

In the meantime, we mostly completed the development of the IIP-Ecosphere platform and we demonstrated it in public, e.g., on two industry fairs. We tracked the requirements fulfillment and identified that about 50% of the expressed demands are implemented. At a glance, this may appear like a failure, but it is important to consider that we a) intentionally also collected requirements for future platforms that are out of scope for realization, b) designing a unified AI toolkit is more challenging than initially expected by the partners, and c) some promised contributions corresponding to larger parts of the requirements are still missing. Further, opportunities arose to realize functions, that were not part of the GA. To play on the safe side, we initially captured such functions as single, low-priority, optional requirements, e.g., a management user interface. Of course, the realization of such requirements, e.g., the user interface, affects the interpretation of the realized requirements.

4 Conclusion

Industry 4.0 or IIoT platforms are the foundation of complex software-driven manufacturing systems. Recent developments may lead to new requirements or even new platforms. We performed an extensive requirements collection from two viewpoints, usage and functional view. Although the usage view was not completed due to resource limitations, both views share a significant overlap and complement each other, also during creation. First experiences have been taken over into the requirements processes of the partners and into ongoing work of LNI 4.0.

Acknowledgments

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References

[1] K. Pohl and C. Rupp. *Requirements Engineering Fundamentals*. Rocky Nook, 2011.

[2] J. Delsing. "Local Cloud Internet of Things Automation". In: *IEEE Industrial Electronics Magazine* (2017), pp. 8–21.

[3] P. Loucopoulos, E. Kavakli, and N. Chechina. "Requirements Engineering for Cyber Physical Production Systems". In: *CAiSE'19*. 2019, pp. 276–291.

[4] P. Agarwal and M. Alam. "Open Service Platforms for IoT". In: *Internet of Things (IoT): Concepts and Applications*. 2020.

[5] H. Eichelberger, H. Stichweh, and C. S. Sauer. "Requirements for an AI-enabled Industry 4.0 Platform – Integrating Industrial and Scientific Views". In: *SOFTENG'22*. 2022, pp. 7–14.

[6] https://doi.org/10.5281/zenodo.4485801

[7] https://doi.org/10.5281/zenodo.4485774