An Agricultural Data Platform iStar Model

Stefan Braun[1], István Koren[1], Marc Van Dyck[2], and Matthias Jarke[1,3]

[1] Information Systems & Databases, RWTH Aachen University, Aachen, Germany
{braun,koren,jarke}@dbis.rwth-aachen.de
[2] Technology and Innovation Management, RWTH Aachen University, Aachen, Germany
vandyck@time.rwth-aachen.de
[3] Fraunhofer FIT, Birlinghoven Castle, Sankt Augustin, Germany

Abstract. Organizations increasingly rely on external data and service exchange within business networks in order to fuel their analytics and artificial intelligence needs. In Industry 4.0 practices, new ecosystems have evolved, where data and service provisioning often happens within dedicated platforms. Hereby, the challenge lies in ensuring the data sovereignty of enterprises in terms of self-determination with regard to the use of their data. While conceptual modeling of these platforms inhabits a large number of opportunities, for instance, including automated generation of access policies, research in this area is scarce. To this end, we propose a bottom-up approach using the iStar 2.0 modeling language. In this paper, we first introduce a model describing the market participants of a data and service exchange platform in the realm of smart farming. We then generalize and provide a formalization of relevant aspects in a broader context. The resulting models serve both as a basis for discussion on the requirements analysis level and as fundamental groundwork for further value generation in the area of data sovereignty in complex cross-organizational settings.

Keywords: Conceptual Modeling · Data Sovereignty · Industry 4.0

1 Introduction

Connected sensors, assets, products, and actors in Industry 4.0 continuously generate an enormous amount of data. The availability, access, and usage of data and applications by multiple parties enable an increase in productivity due to faster and more practical insights. They also enable new value propositions, such as predictive maintenance and dynamic pricing. These effects are reinforced by economies of scale; in the vision of the *Internet of Production* [4] the vast interconnection even allows new business models. Policies and agreements between stakeholders are required to allow for the regulated collaboration of different parties and their subsequent data sharing. An important aspect is thus the question of fair value distribution, i.e., a balance of value creation and value capture between the stakeholders, and a more precise definition of the benefits for data sharing [1]. The first step for the identification of the former—also, but not only, in terms of data use—is to formulate goals, relationships, and interdependencies of the several parties. One exemplary formalized modeling of a data ecosystem platform was conducted by Chakrabarti et al. [2]. The authors describe the data-related interdependencies of users of the alliance-like International Data Spaces platform [8]. From a business management point of view, however, the steps before the established data collaboration are also of great importance. To this end, platform ecosystems evolved that connect various stakeholders from established business partners to emerging market entrants like complementors [12], i.e. businesses that complement the product or service of another company. In this paper, we model interdependencies of platform stakeholders. First of all, this view gives stakeholders an insight on collaboration opportunities. As a particular example, a use case from agriculture is presented. It is based on an on-going large case study of an existing and evolving smart farming ecosystem [13]. Together with domain experts who performed the original study, we identified the business models of manufacturers, dealers, contractors, and farmers, as well as farm management platforms and complementors, and formalized it as an iStar 2.0 model. We then generalize and provide relevant aspects in a broader context. While the model currently serves to derive business model requirements, we see a multitude of possible further use cases, e.g., in the automated generation of data usage policies. The remainder of this paper is structured as follows. First, we introduce a model from the agriculture domain in Section 2 and have a look at a Strategic Dependency (SD) model. In Section 3, we set our focus on the relationship of the data platform with the previously existing ecosystem. Section 4 concludes the paper, discusses the use case of automated policy generation, and gives an outlook on future work.

2 Agriculture Scenario

Since the agricultural sector is one of the driving forces behind digitalization [6,11], it lends itself to closer reflection. In this section, we illustrate identified intersections and interfaces of participants. The Strategic Dependency (SD) model of the use case is shown in Figure 1. It was collaboratively designed in our Direwolf iStar Modeler tool [5]. In the following, we give a brief description of the identified actors and their goals:

Manufacturer The manufacturer's primary goal is to deliver products and services to those linked to the farm. There are two sub-goals: First, selling machines via the dealer, and second, developing and offering innovative services and machines to customers.

Dealer The dealer has the goal of providing land machines and corresponding services to farmers and contractors with the sub-goal to sell or lease machines. The dealer buys machines from the manufacturer and either sells or leases them for a profit to contractors or directly to farmers.

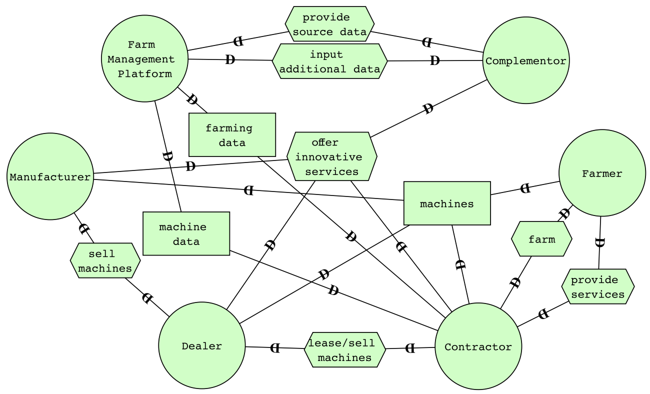

Fig. 1. Stakeholder Relationships as iStar Strategic Dependency View

Contractor The contractor has the goal of providing technical services to farmers by partially or entirely taking over specific farming processes. This goal is supported by the two sub-goals to efficiently and flexibly allocate machines on the one hand and flexibly allocate specialized staff on the other. He obtains the machines from the dealer.

Farmer The farmer's goal is to efficiently raise living organisms for food or raw materials. For this, he has the sub-goals to efficiently use labor, the profitable sale of goods, the efficient use of the machines, and the efficient use of the inputs for seed and crop protection.

Farm Management Platform The farm management platform is a new actor in the agricultural value chain. It can be considered a "new software system for farmers" and integrates all data from the farm and other data streams (e.g., weather) to provide data-based services to those linked to the farm with the sub-goals of being enabling innovative services based on data, facilitation of sales of machines, and the connection of users with suppliers and complementors. Platforms can be managed by a central player [1] or governed by an alliance of different stakeholder organizations [8].

Complementor The complementor aims to offer value-adding digital services to those linked to the farm with the sub-goals to develop and offer innovative services to customers, leveraging data inputs, and providing new data.

The farm management platform relies on the resources farming data and machine data, which it obtains from the contractor, and provides the required data for the development of services to the complementor. The complementor develops new services, which are made available via the farm management platform to the users: The contractor, the dealer, and the manufacturer. Notable in Figure 1 is the dependency direction of the new data services going from bottom to top. The production dependency cycle (i.e., especially the machine dependency cycle) starts on the left, traversing the bottom to the right, before finally concluding in the top. Those two dependencies, the first representing the newly added services and the second representing the previously existing ones, are clearly distinguishable. However, there is a link between the two, since the participants depend on the data service early in the production cycle. In contrast, the new data service depends on the last participants of the production dependency. In total, thus, they build one big cycle.

3 Existing vs. Emerging Market Participants

Of particular interest is the relationship between actors from the former traditional agricultural value chain, i.e. the existing market participants, with the new extended actors centered around the farming platform, i.e. the emerging market participants. Therefore, we merge the emerging market participants - complementor and farm management platform - into one actor and the existing participants manufacturer, dealer, contractor, and farmer into another actor. The resulting SR model is depicted in Figure 2. We get two actors, the emerging

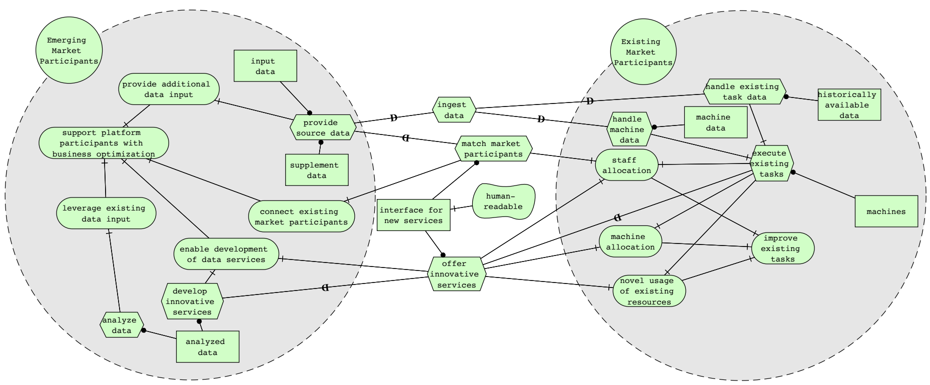

Fig. 2. Abstracted Strategic Rationale Model of Agriculture Use Case

market participant, depicted on the left, and the existing market participant, located on the right. There is an apparent interdependency of those two abstracted actors: The emerging market participant serves innovative services used by the existing market participant and provides the matching of market participants, such that those can find services and providers. Both of these tasks rely on an interface for the new services and system, e.g., a platform. On the other hand, the new participants are dependent on the old participants providing data; all data in the figure revolves around farm and machine data. Therefore we have a cyclic dependency, where each participant relies on the other. For analysis of the abstraction, the interior of the abstracted actors is depicted, emphasizing the most important newly introduced changes within the relationship of the existing market participant and the emerging market participant. For a detailed insight, we refer to the International Data Spaces model [8], as the data spaces' data owner and the data provider are part of our existing market participant. The interface represents the app store provider, data app store, and broker for new services/systems, which we understand as a resource in our model rather than a separate participant and, in our case, is handled by the emerging market participant. The data consumer and data user correspond to the existing market participant using the new innovative service.

4 Conclusion & Future Work

In this paper, we modeled an agricultural data platform in the Industry 4.0. As platform ecosystems in industrial settings are characterized by high complexity in terms of technology layers [10] and relationships [9], and, in addition, ecosystem interdependencies change as they evolve, we found that the iStar notation is superior to previous textual descriptions or non-formalized graphical abstractions, which favor static and simple environments, to reflect the ecosystem interdependencies and dynamics. Adding to the predominantly conceptual and qualitative state of studies on platform ecosystems, future research could use iStar to model different scenarios and compare these to the expected outcomes based on the existing conceptual and qualitative literature. Using this formalization, we can compare scenarios better concerning, e.g., centralization, the structure of the data ecosystem (e.g., alliance-like, one existing participant takes the additional role of a new participant, etc.), the background of new participants, and especially the relationship of emerging and existing participants. The abstracted model emphasizes the significant aspects when considering market entrants, both for comparing different possible scenarios and for using the obtained model for policy generation – as the big picture is to throw a bridge from goals to policies to code using conceptual modeling. The introduced formalized models can be used as a groundwork for code generation tasks for all actors, such as data access policies, user interfaces, and corresponding data models. An exemplary code generation task is permission management to data streams based on the modeled parameters. For instance, access rights may be automatically granted if a relationship edge is drawn in the model; or it may just as well be withdrawn again in the opposite case. To implement this, we may rely on iStar extensions like Secure Tropos [7] or STS-ml [3]. While these models are a necessary first step towards policy generation, it is an important one nonetheless, as we, combined with already existing results for data governance, obtain proper groundwork for future work and already provide some insights.

The synthesis of these ideas by combining the comparison of platform variants with code generation may lead to a faster and more holistic analysis of data ecosystem variants. Ultimately, a repository of available graphical representations and code structures may facilitate automated, easier and faster decision support for stakeholders in new data-driven ecosystems.

Acknowledgement. Funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under Germany's Excellence Strategy - EXC-2023 Internet of Production - 390621612.

References

1. Adner, R.: Ecosystem as Structure. Journal of Management **43**(1), 39–58 (2017). https://doi.org/10.1177/0149206316678451
2. Chakrabarti, A., Quix, C., Geisler, S., Pullmann, J., Khromov, A., Jarke, M.: Goal-Oriented Modelling of Relations and Dependencies in Data Marketplaces. In: Goulão, M., et al. (eds.) Proceedings of the 11th International i* Workshop colocated with the 30th International Conference on Advanced Information Systems Engineering (CAiSE 2018), Tallinn, Estonia, June 12, 2018. CEUR-WS Proceedings, vol. 2118 (2018), `http://ceur-ws.org/Vol-2118/iStar2018_paper_4.pdf`
3. Dalpiaz, F., Paja, E., Giorgini, P.: Security Requirements Engineering via Commitments. In: 2011 1st Workshop on Socio-Technical Aspects in Security and Trust (STAST). pp. 1–8. IEEE (08092011 - 08092011). https://doi.org/10.1109/STAST.2011.6059249
4. Jarke, M.: Data Sovereignty and the Internet of Production. In: Advanced Information Systems Engineering. Lecture Notes in Computer Science, Springer International Publishing, Cham, Switzerland (2020)
5. Koren, I., Klamma, R., Jarke, M.: Direwolf Model Academy: An Extensible Collaborative Modeling Framework on the Web. In: Michael, J., et al. (eds.) Companion Proceedings of Modellierung 2020 Short, Workshop and Tools & Demo Papers, Vienna, Austria, February 19-21, 2020. CEUR-WS Proceedings, vol. 2542, pp. 213–216 (2020), `http://ceur-ws.org/Vol-2542/MOD20-TuD5.pdf`
6. Kritikos, M.: Precision agriculture in Europe: Legal, social and ethical considerations. European Parliament, Brussels, Belgium (2017). https://doi.org/10.2861/278
7. Mouratidis, H., Giorgini, P.: Secure Tropos: A Security-Oriented Extension of the Tropos Methodology. International Journal of Software Engineering and Knowledge Engineering **17**(02), 285–309 (2007). https://doi.org/10.1142/S0218194007003240
8. Otto, B., Jarke, M.: Designing a multi-sided data platform: findings from the International Data Spaces case. Electronic Markets **29**(4), 561–580 (2019). https://doi.org/10.1007/s12525-019-00362-x
9. Schermuly, L., Schreieck, M., Wiesche, M., Krcmar, H.: Developing an Industrial IoT Platform - Trade-off between Horizontal and Vertical Approaches. In: Ludwig, T., Pipek, V. (eds.) Human Practice. Digital Ecologies. Our Future. 14. Internationale Tagung Wirtschaftsinformatik (WI 2019), February 24-27, 2019, Siegen, Germany. pp. 32–46. University of Siegen, Germany / AISeL (2019), `https://aisel.aisnet.org/wi2019/track01/papers/3`
10. Sisinni, E., Saifullah, A., Han, S., Jennehag, U., Gidlund, M.: Industrial Internet of Things: Challenges, Opportunities, and Directions. IEEE Transactions on Industrial Informatics **14**(11), 4724–4734 (2018). https://doi.org/10.1109/TII.2018.2852491
11. Trendov, N.M., Varas, S., Zenf, M.: Digital Technologies in Agriculture and Rural Areas: Briefing Paper. Food and Agriculture Organization of the United Nations (2019), `http://www.fao.org/3/ca4887en/ca4887en.pdf`
12. van Alstyne, M.W., Parker, G.G., Choudary, S.P.: Pipelines, Platforms, and the New Rules of Strategy. Harvard Business Review **94**(4), 54–62 (2016)
13. Van Dyck, M., Lüttgens, D.: Design Faktoren und Strategien für digitale Plattformgeschäftsmodelle im B2B-Kontext am Beispiel der Agrarindustrie. In: Gausemeier, J., Bauer, W., Dumitrescu, R. (eds.) Vorausschau und Technologieplanung. pp. 215–232 (2019)