The Role of Ontologies in Data Spaces for Food Systems – A Conceptual Framework for Ethical Reflexivity and Semantic Interoperability

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Abstract

The digital transformation of food systems has been called a paradigm shift in the midst of a twilight zone. One major aspect of current unclarities consists in the current nature of semantic integration, which poses an obstacle for the emergence of responsible and interoperable data-sharing practices. The sustainability performance of food systems requires monitoring and evaluation, which necessitates semantic integration from dispersed data sources. Semantics and interoperable data spaces can serve as the architecture to solve integration challenges. The adoption of controlled vocabularies facilitates efficient data sharing for both humans and digital systems. However, designing data spaces, specifically for integrating diverse and heterogeneous food system data, presents significant challenges, also for the normative dimension of ethical, legal, and societal aspects (ELSA). For example, to meet sustainability goals, monitoring and evaluation are needed by stakeholders, which come with data integration challenges (both ethical and technical).

We employ an integrative and interdisciplinary literature review with in-depth analyses of Data4Food2030 case studies, to explore the concept of data spaces and understand the readiness of a specified case from multiple dimensions. This work presents and discusses a framework based on food system semantics to facilitate responsible and interoperable data sharing. We suggest addressing the challenges of data integration in food systems which require a comprehensive approach that considers semantics, interoperability, and responsible data-sharing heuristics.

Keywords

semantic interoperability, ethical reflexivity, data economy, food systems

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1. Background

The transformative impact of digital technologies on food systems is evident today as efficiency is enhanced to unprecedented levels. The tangible reality of the ongoing digital transition is signified by the integration of technologies such as IoT-solutions, drones, automated land observation and irrigation structures in modern agricultural practices (Vermesan & Friess, 2016; Popkova & Sozinova, 2022; Dörr, & Nachtmann, 2022; Kumar et al., 2022). In the face of imminent, interrelated challenges such as population growth and resource scarcity, digital solutions appear as a main strategy to optimise harvests and resource consumption (Diamandis & Kotler, 2015). Whether regarding energy use, pesticide control, disease diagnosis or automated calculation, digital technologies such as machine learning, digital twins, prediction models and sensor networks have a clear potential to enhance productivity processes in diverse sectors (European Commission, 2018). Additionally, digitalisation helps to meet stakeholder demand of efficiency.

The digital transformation of food systems, however, is a complex process that involves beyond the dimension of technology also domains such as politics, culture, and ethics. Because of the manifold challenges inherent in aligning novel technical solutions with existing economic, moral and legal value systems, there exists significant doubt regarding future strategies, policies and practices. In fact, the transition has been understood as a "paradigm shift" in the midst of a "twilight zone" (Wolfert et al, 2021). One major aspect of current unclarities consists in the current state of semantic interoperability processes, which are proving to pose an obstacle for the emergence of interoperable data-sharing practices. For example, the sustainability performance of food systems requires monitoring and evaluation, which necessitates semantic integration from dispersed data sources to fulfil the required data needs.

The aim of our work is to address the twofold barrier of ontological classification in the context of Data Economy for Food Systems (DE4FS). Ontology is here firstly meant as a semantic modelling technology deployed in supporting data sharing towards interoperable DE4FS. Secondly, we understand ontology in the broad, philosophical sense of the novel category of being in the form of the digital world as a broader ecosystem of the DE4FS. The latter meaning of ontology entails a range of normative questions, as it concerns the question whether the synthesis between food and digitalisation implies a paradigmatic transformation providing new opportunities for sustainability and equitability or, rather, whether this synthesis precisely perpetuates traditional tendencies of control, calculation and exploitation. With a focus on the value of semantics for improving food system sustainability performance while integrating the technical perspective with critical theory into a normative scope we ask:

Research Questions:

How can we develop an agricultural reference ontology that is compatible and interoperable with the semantics of a farm data space? How can data spaces be responsibly co-designed to accommodate the diverse and evolving data requirements of agri-food system sustainability? How can semantic integration and interoperability enable meaningful data sharing and collaboration across stakeholders within the agri-food system data space?

Prima facie, the two meanings of the concept of ontology, i.e. the technical one and the philosophical one, might not seem to be immediately related. We argue, however, that the technical and the normative domain are closely intertwined and cannot be separated without reducing the full meaning of involved concepts. To demonstrate this, it can be seen how data spaces can serve as the architecture to solve data integration challenges in digital food systems and the adoption of controlled vocabularies facilitates semantics and interoperable data sharing for both humans and digital systems. The way in which these systems take shape accordingly, however, will have concrete consequences for people's livelihoods, farm ecosystems, food habits, population health, power distribution and more. Because these possible outcomes are to some extent implicit to the design of semantics-based systems, it is important that these processes are accompanied by efforts of fundamental ethical reflection.

2. Methods

Some ethical standards are already broadly integrated in existing projects working towards semantic interoperability because the data that is collected and used to conduct research should be aligned with the FAIR principles (Findable, Accessible, Interoperable and Reusable) (Wilkinson et al., 2016). Existing studies in the food system focus on shared understanding by improving semantic interoperability, including proposed reference architectures, concept schemes and information models (Baker et al., 2019; Bilbao-Arechabala & Martinez-Rodriguez, 2022; Brewster et al.; DIVINE, 2023; Falcão et al., 2023; Palma et al., 2022; Roussaki et al., 2022; Routis et al., 2022). Still, a thorough holistic view, including the normative angle, is still lacking to develop a framework that supports assessing real-life cases on their readiness level from multiple dimensions, including semantic interoperability and ethical reflexivity.

By combining efforts from various disciplines focused on similarities in the DE4FS, we build on the existing interdisciplinary ELSA (Ethical, Legal and Societal Aspects) methodology. The ELSA-lab in Wageningen, by embedding analyses of ELSA in research programmes and including various stakeholders from government, civil society, academia and industry in its anticipation of issues and responsibilities, has already linked the involved dimensions (economics, ecology, ethics, law and society) in the concrete context of food systems. For example, the concept of Digital Twins has been critically analysed, showing that these digital real-time copies are not merely objective representations of physical real-life entities but also normative structures steering towards efficiency and optimisation (Korenhof, Blok & Kloppenburg, 2021). In a similar fashion, it has been demonstrated that algorithms are not merely abstract, mathematical data but always engrained in the human, socio-political world and that the very ideal of algorithmic transparency in itself is part of disciplinary power effectuation (Wang, 2022). Thus, technologies co-constitute the world, mediate human experience and understanding, and grow beyond human control which implies they have a 'life' of their own (cf. Blok, 2023).

A major barrier to the radical integration of ethics in digital ontology development is the fundamental way in which 'technology' as a concept is being understood – which brings us the philosophical dimension of ontology at stake here; a major tendency persists to conceive technologies as passive, material instruments, objects or tools, ready to be used by human users. This human is, accordingly, conceived of as the exact opposite of the object, namely as an acting, thinking subject that imposes cognition onto the world and the lifeless things inside it. But semantics-based information systems are not simply products with certain properties in the sense of traditional economic commodities, nor a simple tool or an instrument. Rather, these complex systems radically alter the way in which humans themselves understand the physical- and digital world as digitalisation processes that affect cognition and the nature of knowledge.

The simple example of the Collingridge dilemma elegantly elucidates why technologies are more than just neutral tools. This is all the more true for digital innovations. The dilemma states that technologies are easy to control when its consequences are not yet manifest, yet impossible to control once their moral implications have appeared because of broad usage and integration in society. The Collingridge dilemma demonstrates that the design of any technological artifact is fundamentally at an ethical crossroad. Moreover, it shows that technologies become ingrained in

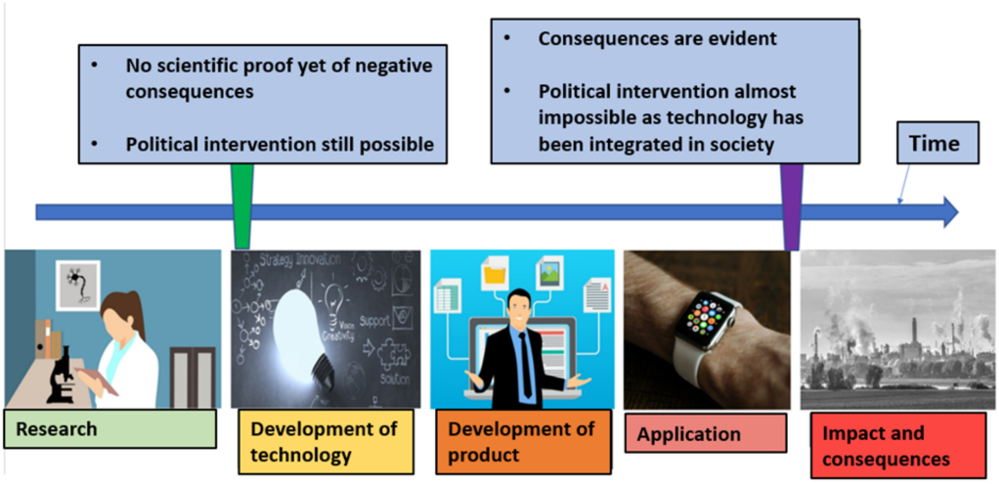

Figure 1: Visual depiction of the Collingridge Dilemma

societal structures, which can have cultural, political, economic and sustainability consequences that, after the broad integration of the technology, cannot simply be made undone or reversed.

3. Results and Discussion

A strictly technical, uncritical approach to broadly integrate information systems might overlook possible negative societal and environmental implications in the future. As the consequences of disruptive technologies are in principle hard to predict, it is necessary to compare existing perspectives on the fundamental relations between humanity, technology, and nature to cover the topic of data in food also from a normative angle. Fields of economics, natural sciences, legal studies, information sciences and ethics should align in interdisciplinary efforts to address these encompassing, interrelated and multidimensional topics. Taking seriously this challenge, we employ an integrative and interdisciplinary literature review with in-depth analyses of Data4Food2030 case studies, to explore the concept of data spaces and understand the readiness of a specified case from multiple dimensions of a DE4FS.

This work discusses the need for a framework based on food system semantics to facilitate responsible and interoperable data sharing. We suggest addressing the challenges of data integration in food systems which require a comprehensive approach that considers semantics, interoperability, and responsible data-sharing heuristics.

4. REFERENCES

Baker, T., Whitehead, B., Musker, R., Keizer, J. (2019). Global agricultural concept space: lightweight semantics for pragmatic interoperability. Science of Food, 3(1), 16.

Bilbao-Arechabala, S., Martinez-Rodriguez, B. (2022). A practical approach to cross agri-domain interoperability and integration. 2022 IEEE International Conference on Omni-layer Intelligent Systems (COINS)

Blok, V. (2023). The Ontology of Technology Beyond Anthropocentrism and Determinism: The Role of Technologies in the Constitution of the (post)Anthropocene World. Found Sci 28, 987–1005. https://doi.org/10.1007/s10699-022-09829-1

Brewster, C., Kalatzis, N., Nouwt, B., Kruiger, H., Verhoosel, J. Data Sharing in Agricultural Supply Chains: Using semantics to enable sustainable food systems.

Diamandis, P. and Kotler, S. (2015). Abundance: The future is better than you think. New York: Free Press.
Dörr, J. Nachtmann, M. (Eds.). (2022). Handbook digital farming: digital transformation for sustainable agriculture. Springer. https://doi.org/10.1007/978-3-662-64378-5

European Commission (2018) Artificial Intelligence for Europe (Communication No. COM(2018) 237 final). European Commission, Brussels.

Falcão, R., Matar, R., Rauch, B., Elberzhager, F., Koch, M. (2023). A Reference Architecture for Enabling Interoperability and Data Sovereignty in the Agricultural Data Space. Information, 14(3), 197.

Korenhof, P., Blok, V. Kloppenburg, S. Steering Representations—Towards a Critical Understanding of Digital Twins. Philosophy of Technology. 34, 1751–1773 (2021). https://-doi.org/10.1007/s13347-021-00484-1
Kumar, A., Kumar, P., Singh, S. S., Trisasongko, B. H., Rani, M. (Eds.). (2022). Agriculture, livestock production and aquaculture : advances for smallholder farming systems (Vol. Volume 2 /). Springer. https://doi.org/10.1007/978-3-030-93262-6

Palma, R., Roussaki, I., Döhmen, T., Atkinson, R., Brahma, S., Lange, C., Routis, G., Plociennik, M., Mueller, S. (2022). Agricultural Information Model. In Information and Communication Technologies for Agriculture—Theme III: Decision (pp. 3-36). Springer.

Popkova, E. G., Sozinova, A. A. (Eds.). (2022). Agrotech : ai, big data, iot. Springer. https://doi.org/10.1007/978-981-19-3555-8

Roussaki, I., Doolin, K., Skarmeta, A., Routis, G., Lopez-Morales, J. A., Claffey, E., Mora, M., Martinez, J. A. (2022). Building an interoperable space for smart agriculture. Digital Communications and Networks. https://doi.org/10.1016/j.dcan.2022.02.004

Routis, G., Paraskevopoulos, M., Vetsikas, I. A., Roussaki, I., Stavrakoudis, D., Katsantonis, D. (2022). Data-Driven and Interoperable Smart Agriculture: An IoT-based Use-Case for Arable Crops. 2022 IEEE International Conference on Omni-layer Intelligent Systems (COINS)

Vermesan, O., Friess, P. (Eds.). (2016). Digitising the industry: internet of things connecting the physical, digital and virtual worlds (First, Ser. River publishers series in communications, v. 49). River. https://doi.org/10.1201/9781003337966

Wang, H. Transparency as Manipulation? Uncovering the Disciplinary Power of Algorithmic Transparency. Philosophy and Technology, 35, 69 (2022). https://doi.org/10.1007/s13347-022-00564-w

Wolfert, S., Wassenaer, L. van, Burg, S. van der, Ryan, M., Klerkx, L., Rijswijk, K., McCampbell, M., Athanasiadis, I., Beers, G., (2021). Navigating the twilight zone: pathways towards digital transformation of food systems. Wageningen University Research. https://doi.org/10.18174/552346