SMARAGD: Data Interoperability for Decision Support in the Norwegian Agrifood Sector

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Abstract

Norwegian land-based food production faces significant challenges driven by evolving weather patterns, rising operational costs, and labour scarcity. In response, there is a pressing need for enhanced strategies rooted in real-time field insights. This necessitates the adoption of smart sensor-driven agritech technologies and data-driven precision farming solutions. While these technologies generate vast datasets, their transformative potential is hindered by interoperability gaps at data and API levels, constraining their adoption and utility. To address these limitations, the SMARAGD project focuses on enhancing data interoperability to integrate diverse datasets and leverage the synergistic effects of combined data, while also fostering opportunities for data providers to monetise their contributions. Through a plug-in architecture adhering to industry standards, SMARAGD aims to integrate diverse agritech data sources and services, presenting tailored insights to end users for informed decision-making. By enabling seamless data exchange and reducing manual efforts, this initiative promises to enhance productivity and profitability for farmers while enabling data providers to unlock the value of their interoperable data assets.

Keywords

Data Interoperability, Data Space, Smart Agrifood, Decision Support, FIWARE, Smart Data Models

1. Introduction and Motivation

Land-based food production in Norway struggles with razor-thin margins due to the changing weather conditions, increased operational costs, and difficulty of acquiring sufficient manual labour. Farmers who intend to stay in the business need an improved strategy that is driven by a better understanding of what is going on in their fields in real-time. This can be achieved by investing in smart sensor-driven agritech technologies and using data-driven precision farming solutions. Sensors produce massive amounts of valuable data, and are often coupled with some real-time data monitoring and visualisation tools. These technologies aim to help end users in the agrifood sector to monitor farms in real-time, as well as to maximise productivity and profitability in farm and business operations with minimum efforts. To support everyday food production and farm management processes, farmers rely on multiple available information sources, which need to be combined to produce valuable insights, e.g. to assess soil composition, control fertiliser and pesticide types, or obtain accurate yield estimates. Using a combination of static sensors planted in the soil, moving robotic platforms that cover the whole height of the plants, and aerial drones, together with human experience and knowledge, a farmer can take informed decisions based on facts following precision agriculture principles [1].

In practice, despite the availability of smart sensor-driven solutions in the Norwegian agrifood sector, their widespread adoption and ability to meet end users' needs remain limited. This constraint largely

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stems from the lack of interoperability at the data and API levels [2]. Consequently, despite the diversity of innovative sensor technologies, the exchange of data and services among these solutions is hindered, impeding their full potential to address the diverse requirements of agrifood stakeholders in Norway. To this end, the **SMARAGD** project[1] (**Smart Agriculture Data Fusion for Decision Support**) will build a data and service interoperability layer to enable the creation of data-driven decision support services for the land-based food industry. This will be achieved through an extensible plug-in architecture, where individual agritech data sources and services will be integrated following established standards and protocols, and offered to end users in an understandable and tailored manner to support decision making. This, on the one hand, will allow farmers to maximise productivity and profitability in farm and business operations with reduced manual efforts and costs, and, on the other, will allow data providers to monetise their interoperable data assets.

The project brings together applied researchers and agritech providers delivering precision farming solutions to the Norwegian land-based food industry – namely, sensor-based environmental monitoring, spraying and aerial inspection using drones, and soft fruit harvesting robots. With these companies, representing the three dimensions of precision agriculture and providing complementary expertise, the project tackles the challenges in a holistic manner, aiming to make the results re-usable by the wider agritech community. In doing so, the project addresses Norway's national goal of increased value creation in agriculture by laying the foundation for profitable and sustainable value chains in land-based food production, including the income opportunities and ability of farmers to invest in their farms, and to promote the efficient and profitable use of a farm's combined resources.

2. Research Pillars of the SMARAGD Project

To address these challenges, it is required to conduct extensive R&D work to implement a holistic solution to enable *(i)* interoperability across siloed vertical agritech services and data sources, *(ii)* end-to-end transformation from disjoint raw datasets into a semantically interoperable open data space, and *(iii)* 'one-stop shop' user experience via an integrated farm management platform for tailored decision support and data monetisation. As such, this R&D work is structured into the following pillars:

Pillar I: Interoperability of Agritech Services and Data Sources Agritech services and data sources often operate in isolation, adhering to varied standards and protocols, complicating interoperability at both API and data model levels. Modern agriculture needs integration of diverse data types, from crop yields and soil composition to rainfall, across formats like spreadsheets and maps. Effective fusion within a unified system requires semantic interoperability, where data meaning and context are consistently defined. To address this, SMARAGD will use existing multi-dimensional data from project partners, legacy systems, and external sources such as weather forecasts and satellite imagery. It involves reusing and expanding existing data models, as well as defining new ones, across three key agritech areas. By standardising data representation and ensuring semantic clarity, the platform will enable effective correlation of datasets across spatial and temporal dimensions, creating a robust context information management layer and enhancing decision-making based on unified data.

Pillar II: Agritech Data Pipelines Integrating agritech services and datasets involves transforming various raw data types, such as non-SQL, time-series, and imagery, into interoperable assets. This requires creating data pipelines spread across the computing continuum that accommodate each data type's distinct characteristics [3]. For example, harvesting robots process images in real time on-site, while weather sensors and drones transfer data with minimal pre-processing. Designing these pipelines involves planning data processing steps, tools, and hosting to convert raw data into a usable format. The project will design data pipelines that standardise and unify diverse data assets within a centralised digital space. Using a shared data model, these pipelines will process collected raw data as it is transferred from its original source and aggregate it into a central farm management platform [4, 5].

[1]https://www.sintef.no/en/projects/2022/smaragd-smart-agriculture-data-fusion-for-decision-support/

Following a modular architecture, this will allow flexible integration of new components or processing steps as needs evolve. This approach ensures efficient, scalable, and adaptable data processing, enabling integration and utilisation of transformed data.

Pillar III: User-Tailored Decision Support and Data Monetisation Building a unified farm management platform for tailored decision-making and data monetisation requires integrating various interoperable data assets into a cohesive system. This platform will handle multiple data types and provide a seamless user experience for querying and visualising information. It will provide a flexible interface that meets end users' specific needs, enabling informed decisions and effective data monetisation. The project will implement synergetic data fusion, combining diverse, previously disjoint data sources to create accurate and valuable insights [6, 7]. By ensuring meaningful data representation and interoperability, the platform will facilitate geo-spatial and temporal data integration [8]. This will support comprehensive decision support services and tools, offering a unified access point for integrated, semantically interoperable data. It will also provide customisable querying and visualisation options, as well as enable external data sharing and monetisation.

3. Implementation: FIWARE Reference Architecture and Smart Data Models

The FIWARE reference architecture and technology stack, underpinned by a collection of industry-adopted data models, offer a comprehensive framework for building interoperable systems within the smart agrifood sector [9, 10]. At its core, the FIWARE architecture is designed to enable seamless integration and interoperability among various components and data sources. It employs a set of open standards and APIs that facilitate the exchange of data and services across different platforms and applications. The architecture is based on a modular approach, allowing developers to leverage and extend existing components to suit specific requirements. The FIWARE technology stack comprises a range of components and tools that support various aspects of smart agrifood systems.[2] For instance, the Orion Context Broker provides a central hub for managing and processing real-time data streams, while many other enablers serve to provide integration with external data sources and sinks, data analytics, visualisation, application development and many more.

One of the key features of the FIWARE architecture is its emphasis on standards-based data models and interfaces. These standardised models, also known as Smart Data Models,[3] ensure consistency, compatibility and interoperability across different systems and domains, including smart agrifood. These models define common data structures and semantics for representing domain-specific information such as crops, weather conditions, and sensor measurements. By adhering to these standardised models, stakeholders across the agrifood value chain can exchange data seamlessly and leverage shared insights for improved decision-making and innovation. Standardising data representation using Smart Data Models enables seamless integration and aggregation of heterogeneous data from diverse sources such as IoT sensors, robots, and drones, as well as legacy data from external databases and services. This harmonisation of data promotes interoperability, enabling stakeholders to access and leverage shared insights for improved decision-making, resource optimisation, and innovation. Moreover, Smart Data Models also foster external collaboration and knowledge sharing within the wider agrifood ecosystem by providing a common language for describing and understanding domain-specific concepts and relationships. As a result, stakeholders can more effectively collaborate on data-driven initiatives, and mutually benefit from publishing and monetising their interoperable datasets and services. This high-level view on the SMARAGD project is depicted in Fig. 1.

[2] https://www.fiware.org/catalogue/
[3] https://smartdatamodels.org/

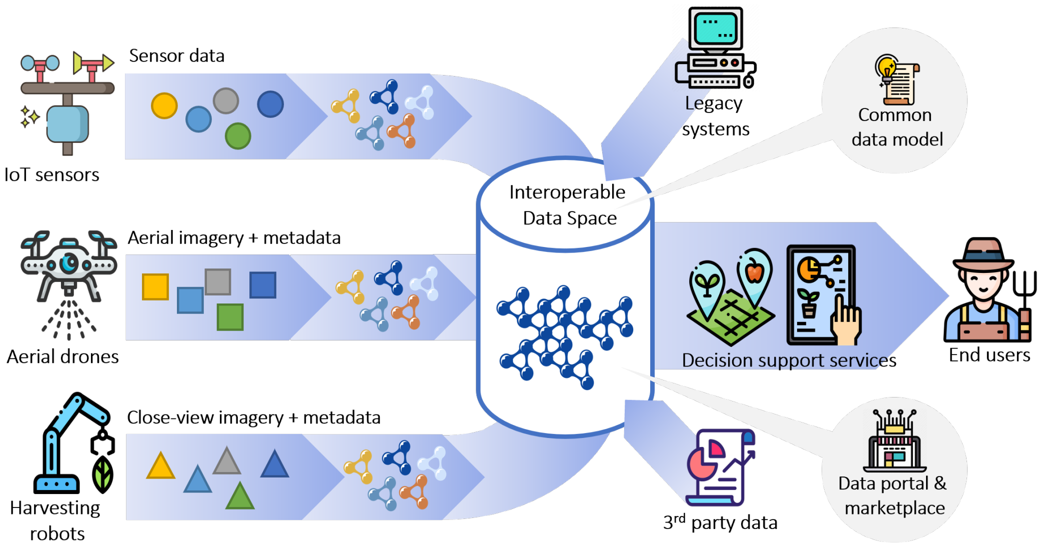

Figure 1: Conceptual architecture of the SMARAGD project.

4. Expected Results

SMARAGD is implemented in an incremental way, generating value for the project partners and the end users at each step. As a result, land-based food producers will be offered an enriched (i.e. based on multiple correlated data sources) view on their farms to support decision making. The developed platform and integration APIs will follow interoperability principles also allowing project partners to integrate with third parties beyond the project, thus aiming to be part of an even larger open ecosystem. More specifically, the expected innovations are the following:

1. **Unified data model for land-based food production**: this will be a common vocabulary of terms for the three precision farming branches (IoT sensors, aerial drones, harvesting robots), aligned with the standards currently being developed by the industry, to maximise reusability and wider adoption. Such a standard model for representing data assets will allow companies to move away from the currently adopted ad-hoc siloed ways of representing data and enable integration with third parties within an open ecosystem.
2. **Generalised data pipelines for the three agritech branches**: to become interoperable data assets and converge in a single shared data space, raw datasets need to go through a sequence of transformation and management steps. The design and implementation of the pipelines for each agritech branch will vary. The goal is to start from company-specific requirements, aiming to generalise across the whole family of similar agritech systems to foster reusability. Having the pipelines in place, the project partners can already start commercialising their interoperable data assets through standard open APIs.
3. **Integrated farm management platform**: such a cloud-based platform will serve as a convergence point for interoperable agritech pipelines, integrating multiple data assets into a common data space. From the end user's perspective, the platform will enable 'one-stop shop' experience, i.e. using client apps, farmers will consume offered data services from one single pool in a transparent, unified and tailored manner. This way, project partners will multiply the value of their own data by combining it with third parties, as well as reach out to new customers. The platform owner will also benefit from providing access to this marketplace to third party agritech data providers and consumers.
4. **Data fusion for decision support**: by implementing geo-spatial and temporal data fusion over previously-disjoint data assets, together with data querying and visualisation tools, we will facilitate decision support specifically tailored to end users needs. The ambition is to provide farmers with an enriched view on their crops and enable them to make decisions over multiple correlated data sources, which produce a more complete, consistent and accurate overview of farm resources than

that provided by any individual data source alone.

5. **New business models**: by entering the Big Data market, the partner companies will adjust their business models, currently mostly focused on hardware products or physical services. The new models will consider both B2C (data-driven decision support to end users via a farm management platform) and B2B (selling interoperable data to third-parties) scenarios.

5. Conclusion

By implementing the described three research pillars, the SMARAGD project unifies precision farming technologies (IoT sensors, robotics, and drones) into a single, interoperable system to enhance agricultural productivity and sustainability through advanced data integration and user-centric solutions. The project's innovations include a unified data model for precision farming, generalised data pipelines, an integrated farm management platform for seamless data access, enhanced decision support through data fusion, and new business models for data commercialisation. This way, the project delivers value to partners and users by offering an integrated view of farm data for better decision-making. The approach, inspired by existing models and tools from the FIWARE community, ensures compliance with industry best practices and regulations.

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