Interoperability and Analysis System for Robots and Data Services Integration in Agriculture

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***Abstract*— This paper presents an interoperability network for the integration of robots and data services for data-driven farming applications. The service-oriented interoperability network is currently under development in the context of the ATLAS project, funded by the Horizon 2020 program framework. The overall goal of the research is to significantly increase the interoperability for digital agriculture and to build up a sustainable ecosystem for innovative data-driven agriculture. The benefits of proposed framework will be proved within a multitude of pilot studies and Innovation Hubs, where the benefits of digital agriculture will be demonstrated to a network of end-users, service providers, researchers and policy makers along the agricultural value chain.**

***Keywords*— robots and data services integration, interoperability and analysis network, data-driven agriculture**

I. Introduction

Data acquisition services and advanced data processing and analysis capabilities are key factors for the simultaneous increase of sustainability and productivity of agricultural operations. Although a multitude of technical solutions and services for data-driven agriculture already exist, the lack of interoperability and the predominance of manufacturer-specific closed solutions demand a careful choice of machines, sensors and data processing platforms and hinder the flexible adaption of these systems to the individual farmer's needs and knowledge exchange [1].

ATLAS [2] will overcome these problems through an open, flexible and distributed Interoperability Network, which enables the seamless interconnection of sensor systems, machines and data analysis tools. ATLAS will provide the means necessary to turn the large amount of collected data into usable knowledge and will provide support to share and exchange this knowledge in order to make informed decisions. The benefits of the ATLAS network will be demonstrated through several pilot studies and *Innovation Hubs*, i.e., centres of competence aimed at bringing together the relevant stakeholders along the digital agricultural value chain on a regional and European level, enabling a faster market take-up of innovative technologies and providing new market opportunities for innovative data service providers.

This paper will present the design and first steps towards the development of the ATLAS service architecture with a specific focus on the aspects related to interconnection of robots, agricultural machinery and data services, dealing with critical agricultural tasks such as crop monitoring, irrigation, and soil mapping and characterization by both remote and proximal sensor devices.

In the rest of the paper, first the main data acquisition and analysis services integrated in the ATLAS platform are described. Then, the interoperable service architecture is presented. Finally, an overview of ATLAS pilot studies and Innovation Hubs is provided.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement ATLAS, No. 857125.

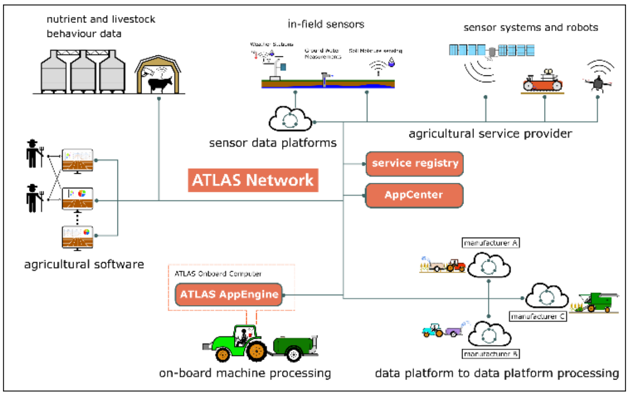

Fig. 1. High-level overview of the ATLAS Interoperability Network with its different components to interconnect sensors, sensor platforms and machinery.

II. Data Acquisition and Analysis Services

Multiple data acquisition and analysis services will be integrated in the ATLAS platform, so that data can be used for decision support. These will include:

- data collection services for crop monitoring: spectral and imaging sensors, LIDAR, remote sensing data and UAV data will be collected and analysed for tasks such as disease detection and plant stress detection, individual plant reconstruction and characterization (e.g., volume estimation). Adaptive data fusion architectures as well as the most advanced machine learning/deep learning algorithms are currently being developed to provide input for decision support purposes [3] [4] [5];
- irrigation oriented data collection and analysis services from multiple sources: this service will deal with soil moisture modelling, satellite temperature analysis services to build high spatio-temporal land surface and air temperature maps, and irrigation data analysis services to analyse data from remote and IoT data;
- vehicle fleet navigation services for robots and production machinery: data acquired from UGVs and agricultural vehicles onboard sensors will be processed for the automated online estimation of key parameters of the terrain that affect its ability to support vehicular traffic, as well as to provide high resolution maps of crops and soil [6] [7] [8];
- livestock monitoring services: data from multiple sources will be acquired and processed for animal health and feeding status monitoring.

III. INTEROPERABILITY NETWORK'S SERVICE ARCHITECTURE

The schematic of the platform concept is shown in Fig. 1. The development of the ATLAS approach is a bottom up initiative that focuses on technical interoperability. The technical concept of ATLAS to achieve the interoperability and improved integration of sensors, agricultural machines and data processing services online and offline is based on two approaches, which complement each other in the ATLAS Network:

- ATLAS Services: the ATLAS services aim at a service-oriented architecture, which enables the connection of Internet-based sensor networks, data platforms and data processing services in a consistent and easy way;
- ATLAS Edge Computing Platform: the ATLAS Edge Computing Platform, called AppEngine, is a reference platform that extends the ATLAS Network to on-premises devices that may need to function in off-line modes (fields with little or no Internet access) or that require low-latency or pre-processing of high-volume data. It is designed to provide a standardized runtime environment on which fit for purpose apps may be readily implemented and deployed.

The architecture is designed along a set of real-world use cases defined in cooperation with the relevant end-users and stakeholders and is shaped by a set of fundamental drivers:

- open to anyone being able to participate with the lowest possible entry barrier;
- decentralized with no central storage and only minimum central components;
- interoperable with supporting well-defined current standards for communication and data formats;
- ability to evolve the interoperability and to react fast to emerging needs and innovation;
- providing offline functionality to different use cases;
- easy to use through automation and simplification.

To achieve this, ATLAS envisions a kind of service mesh architecture where every participant stays autonomous and is responsible for implementing and providing the services offered. Services are organized in a single taxonomy where each service kind, henceforward referred to as service template, formally defines context, functions, API style and their respective request and response data formats. Participants will be able to extend the function of their software by looking up and integrating the service, implementing a template, suiting best their needs. With this architecture, central components are kept to a minimum, namely a Service Registry, through which services implementing a needed function (template) can be discovered and connected.

IV. PILOTS AND INNOVATION HUBS

ATLAS will conduct 13 pilot studies on the test sites and within the farms of the consortium's farming partners to demonstrate and evaluate the platform and the interoperability of sensors, machines and services themselves, as well as the various sensors and the corresponding data analysis services. The pilot studies are aligned along concrete agricultural use cases which were identified during the formation of the consortium and worked out in close cooperation with the farmers. The use cases cover the following topics:

- Targeted application of plant protection
- Advanced Irrigation Management
- Soil state and soil readiness analysis
- Behavioral analysis of livestock

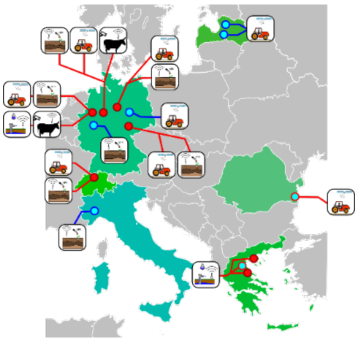

Fig. 2: Overview of the pilot studies location.

ATLAS' concept to establish sustainable ecosystems based on innovative data-driven services is the build-up of so-called Innovation Hubs: a network of end-users, service providers, researchers and policy makers along the agricultural value chain. The innovation hubs are geographically located at the project's pilot studies locations (Fig. 2); hence each innovation hub has initially a dedicated topic-specific focus. However, the range of topics worked on within an Innovation Hub is not restricted to this specific focus. We envision the establishment of special interest groups for arbitrary topics related to digital agriculture if the network's participants see an advantage of this. The innovation hubs provide a place to meet and inform. Located at the pilot studies test sites, the Innovation Hubs provide the necessary environment to demonstrate new technology in a real-world operational environment.

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