Dataspace Forestry 4.0

Networking Digital Twins in a dataspace to realize forestry processes

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Dataspace Forestry 4.0 addresses the inherent need of the forest-based sector for a comprehensive, sovereign and trustworthy networking of its stakeholders and their processes. We therefore consider the innovation potential to be very high. While Dataspace Forestry 4.0 currently focuses on its first application scenarios (sustainability data for forest stands; wood supply chain and its carbon footprint) and their stakeholders, its universal design makes it applicable to all forestry processes. The goal of this presentation is to provide an insight into its technological approach as a basis for discussing design decisions and implementation aspects.

The forest-based sector comprises numerous stakeholders with very different requirements and diverse processes. Many software solutions already exist, but they are often complex, not open or do not enable end-to-end networking along the value chains. The traditional manufacturing industry and other industries encountered similar challenges that Industry 4.0 tries to tackle. Forestry 4.0 [1] adopts Industry 4.0 concepts and technologies like the digital twin and the Internet of Things (IoT). To be networked, all so-called assets involved in a process (e.g., forestry machinery, forests, sawmills or the wood itself) are given a digital twin as a virtual image that represents them in the information world. This is combined with software services for overarching tasks (e.g., simulation or orchestration) and people are integrated via human-machine interfaces (HMI), i.e., mobile apps or desktop applications. Figure 1 gives an overview. Digital twins with their assets, software services and HMI make up the "things" that are networked using an IoT infrastructure. These Forestry 4.0 things are flexibly networked to realize various processes in the forest-based sector, e.g., harvesting, carbon balancing, timber procurement, forest management, or forest information.
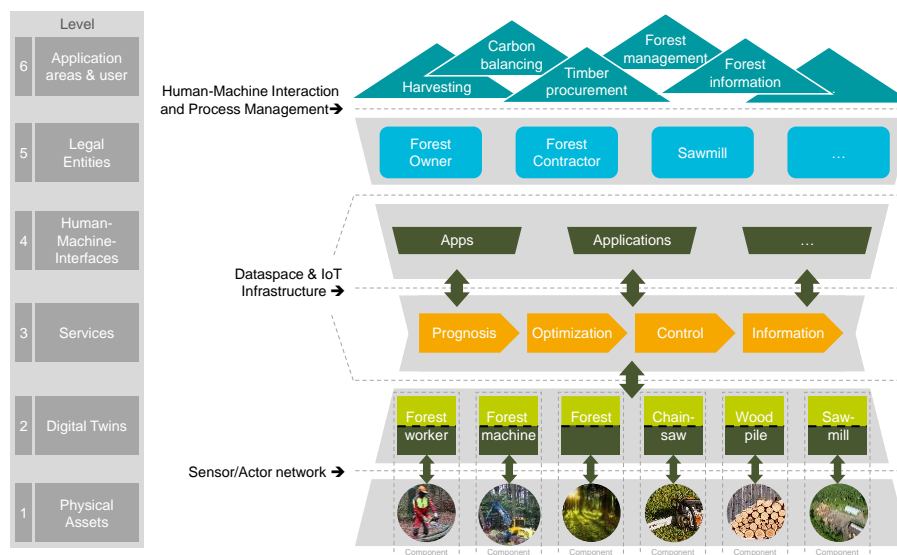

Figure 1: The architecture of Forestry 4.0 "things" to realize various processes in the forest-based sector [1]

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[1] Derived from Bosch Software Innovations 2012. A. Böhm (forest worker), HSM (forest machines), Pixabay (rest)

In contrast to Industry 4.0, Forestry 4.0 needs to consider special requirements of the forestry domain. Forest stands in the sense of production sites are exposed to wind and weather, often have restricted network accessibility, must fulfill economic, ecological and social requirements, and are mostly freely accessible (e.g., by owner, forestry department, hunter, tourists ...). Moreover, the number of stakeholders is very large (e.g., around one million private forest owners in Germany [2]) and very diverse (forest owners, forestry contractors, haulers, sawmills etc.).

In [1], we use our lightweight yet centralized IoT infrastructure – the Smart Systems Service Infrastructure (S³I) – for a decentralized networking of Forestry 4.0 things. In its core, S³I combines identity management, a directory service and a message broker. This way, Forestry 4.0 things networked with S³I already enable secure data exchange and offer a high degree of (data) sovereignty "by design", as digital twins, services and HMIs can be operated individually and independently of each other. However, there is a demand to operate individual S³I instances to increase self-sufficiency, data sovereignty, flexibility and portability in relation to the IoT infrastructure itself as well. For this reason, we are integrating the S³I concept into a Gaia-X-compliant [3] data space – the Dataspace Forestry 4.0 [4]. Figure 2 outlines its basic idea.
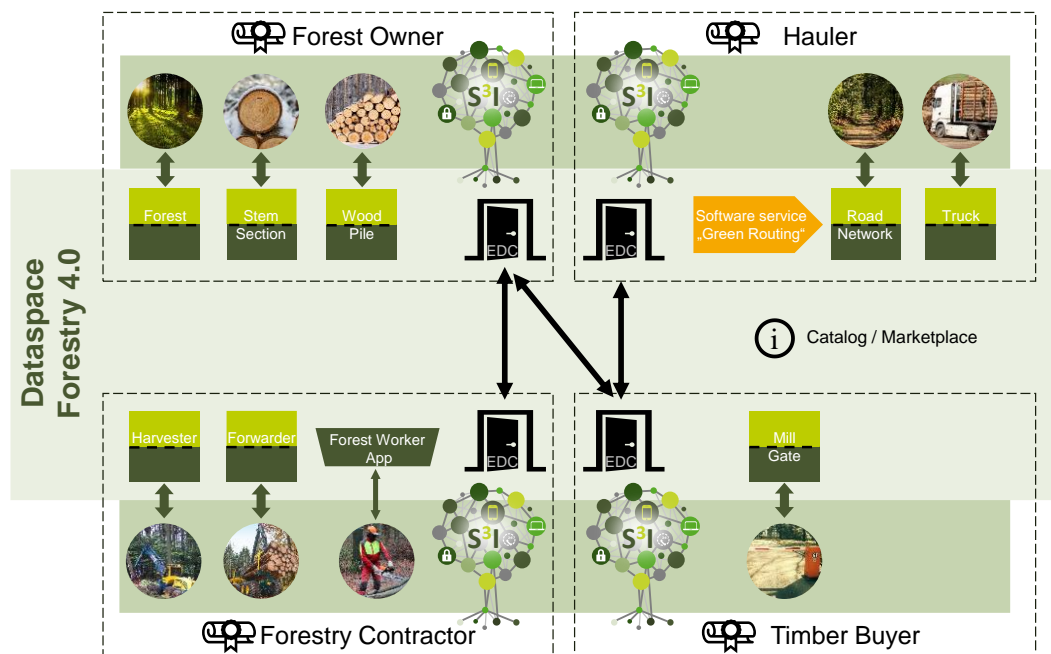

Figure 2: Basic idea of Dataspace Forestry 4.0

The Forestry 4.0 things of individual institutions (e.g., forest owner, forestry contractor, hauler, timber buyer) use their own S³I instance to realize internal processes. On an inter-institutional level, the dataspace infrastructure is used to connect these initially isolated IoTs yielding a federated IoT. For this purpose, Gaia-X federation services (GXFS) [5], the Gaia-X Digital Clearing House (GXDCH) [6], and connectors based on the Eclipse Dataspace Components (EDC) [7] are currently being put to test.

In this context, the digital twins and the S³I are also being transferred to the Industry 4.0 standard of the Asset Administration Shell (AAS) [8], [9], [10]. This further standardization leads to an increase in interoperability and, in particular, opens up the direct use of numerous software modules from the Industry 4.0 area [11].

In Dataspace Forestry 4.0, the shared data is the information exchanged between digital twins of the federated IoT. However, data is always shared in a context. To make this explicit, forestry

processes, e.g., timber harvesting, are formally modeled and provided as templates. The dataspace marketplace is used to provide such processes as service offerings that are instantiated and configured, e.g., when a forest owner and a forestry contractor agree on a measurement. In the course of this, the necessary contracts for the data exchanges between the process's resources are fixed, e.g., the digital twin of the owner's forest needs to provide the necessary tree data to the digital twins of the forestry machines that in turn need to provide production results including their carbon footprints.

Currently, the infrastructure for Dataspace Forestry 4.0 is iteratively being built up and tested with its two first application scenarios: sustainability monitoring in the data space (focusing on sustainability data for forest stands) and sustainable, climate-positive wood value creation (focusing on the wood supply chain and its carbon footprint).

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