White Paper

Semantic Container

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Content

1 Introduction

Today, the economic potential of data as a driver for technologies involving machine learning and big data analytics methods and its role as a cornerstone of modern economies is largely undisputed. Although data is often likened to scarce natural resources such as oil, a major difference is that data can become more useful the more it is used. Nevertheless, despite open data initiatives and some efforts to create markets for data in particular domains, as of today large amounts of data remain to be monopolized. Moreover, potential data users continue to face troublesome and time-consuming hurdles when trying to buy, access or work with data from external sources.

This is unfortunate, given that data can be replicated and moved at very low cost and can generate great economic value when shared. Anyhow, only a few successful data markets have been established, which may be attributed partly to technical issues and partly to business rationale and questions over the viability (and sometimes legality) of business models built around the sale of data. A lot of these issues can be attributed to the problem that data providers selling data (rather than just access to data) largely have to give up control under which terms the data will be used. On the other hand, from a data consumer perspective, both technical challenges and limited trust in the quality, completeness, and origin of the available data have contributed to the restricted adoption of data markets today. This highlights the need for a light-weight, non-time consuming, transparent, standardized, open source, clearly defined and user-friendly solution for data provisioning between involved parties.

Semantic Containers tackle these challenges by developing a standardized infrastructure for data provisioning. The proposed concept allows data providers to efficiently distribute data without giving up control over its usage and monetization while providing data consumers with efficient and well-managed mechanisms to obtain and integrate data in a trustworthy and reproducible manner. By packaging data and processing capabilities into reusable containers, describing the semantics of the content and permissible usage, and providing uniform interfaces, a data set becomes a commodity with well-defined content, properties, quality and usage policy, as well as clear ownership and a price tag.

The solution will leverage existing container technologies such as Docker, which already provide scalable mechanisms for deploying complex software assemblies and use them as a foundation for an infrastructure for data discovery, provisioning, and integration. To create a commodity market around data requires a given set of rules that will be captured in semantic descriptions and enforced through cryptographic methods for proving ownership, and blockchain technology to guarantee immutability. Complete audit trails of data sources and processing steps provide gapless provenance and allow full reproducibility.

2 Roles and Needs

This section provides further information on key actors involved in the Semantic Container ecosystem with a special focus on individual roles and needs addressed by the proposed solution.

2.1 Data collector

A data collector provides services for collecting, storing and managing data. Data collectors need to setup data collection mechanisms, allowing individuals to donate data (data donation), while tracking the sources of collected data. Moreover associated rights and consents with regard to the collected data and the use of this data need to be made explicit.

Examples:

- research institutions (citizen science project)
- official institutions/associations (diabetes data collection in Denmark)
- data journalism
- pharmaceutical industry (medical studies and trials)

2.2 Data Providers

A data provider makes data available for others to use, sets prices and defines usage policies. Data providers need to find customers for selling data and generally aim at increasing the access to and usage of data while participating in a liquid data market. To do so data providers need to package data, define associated usage policies and track the use of provided data (openness, transparency).

Examples:

- Central Institution for Meteorology and Geodynamics (ZAMG)
- Collaboration for Earth Observation (EODC)
- Open Data Portal
- Harptech (robotic sensor platform Verner)
- Scientific data

2.3 Data User

A data user handles data and services provided by Semantic Containers for commercial or non-commercial purposes, e.g. research as well as product or app development. Typical tasks of data users include data aggregation, statistical analysis, predictions and visualization of results. Data users need to find and compare relevant data sources. They are looking for a simple infrastructure to access data in a timely manner and to exchange data in a defined, reproducible, and automatically verifiable way. Automating manual tasks for distributing, cleaning and verifying data as well as keeping track of changes in data and code to reliably reproduce analyses are key functionalities in this regard. In addition data users need to be able to combine semantic containers into data pipelines for data driven applications.

Examples:

- researchers
- students
- data scientists

2.4 Container Developer

A container developer researches and develops novel approaches to solve specific problems and makes them available as Semantic Containers to be used by data users. A container developer is typically in need of a documented environment with defined input and output, agnostic to programming language and development tools and requires automated testing tools.

Examples:

- data scientist
- software developer

2.5 Example Scenario

In the following, the individual roles are further illustrated with the help of an example.

Data Collector

Research institute seeks data for a study: "*How many different grocery stores do people typically visit per week?*"

To do so, the data collector sets up a data collection mechanism for GPS phone data donations from local residents. In addition, students of the research institute actively approach and inform residents about the possibility to provide GPS phone data, indicating which grocery stores have been visited within the past week.

Data Provider

Open data provides records about GPS coordinates of grocery stores, whereas local residents donate GPS data collected on their phones (data donations).

Container Developer

The container developer creates a process container to anonymize (apply differential privacy) on individual GPS data.

Data User

A Data Scientist creates a Jupyter Notebook to aggregate open data and anonymized data for answering the research question.

3 Semantic Containers

3.1 Characteristics

The needs of the individual roles in section 2 are addressed by the following characteristics of the proposed solution. Section 4 describes what technologies are used and how these characteristics are achieved.

Managed
Semantic Containers provide a defined, reproducible, and automatically verifiable data status.

Distributed
Semantic Containers support data exchange between two parties without the need for a centralized intermediary.

Discoverable
Semantic Containers make it easier and faster to find suitable data and allow to identify and compare similar data sets.

Packaged
Semantic Containers combine data, semantic description and program logic in one distribution mechanism.

Composable
Semantic Containers can be combined in sequence for creating a data processing pipeline.

Tradeable
Semantic Containers provide an easy way to sell data and unambiguously describe the usage rights for the data.

3.2 Interoperability Levels

Information about data to be processes can be available on different levels. Sometimes there is only metadata available, other times there is also a defined syntax for the records available, and in the ideal case it is possible to describe the exact semantics of the data at hand. Semantic Container take into account that data sources are not always described in a well-defined way and the proposed solution enables user to enrich the available data in a step-wise approach.

A Semantic Container describes the container input and output on three possible levels:

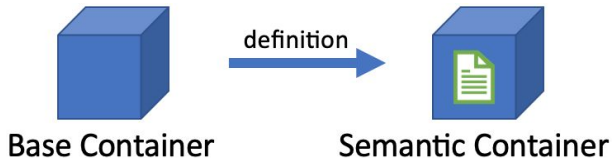
1. **Metadata Level:** every container includes the publisher of the data as well as a verbal description of the content; additionally, the allowed usage, provenance, and optional billing information is provided
2. **Syntax Level:** on this level it is possible to specify and validate the data format (syntax) of the data processed and stored by the container; this information can be used to check compatibility between container

3. **Semantic Level:** the highest level of interoperability includes metadata and syntax information as well as a semantic description about the individual data attributes; on this level it is possible to automatically validate data and ensure a defined level of data quality

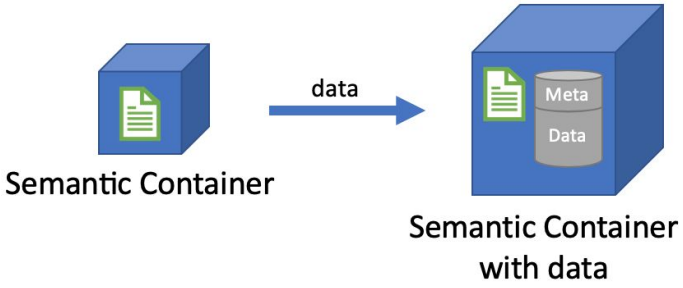
3.3 Workflow

The following steps describe the typical life cycle of a Semantic Container:

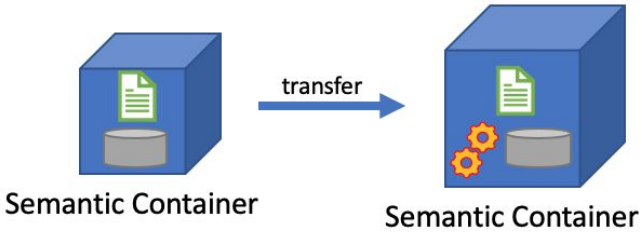
1) Setup a semantic container, based on a base container by providing a definition of data and a specific usage policy



2) Data is transferred into the container via a API endpoint and this method performs automatic data validation and generates a complete audit trail



3) Process data by chaining together semantic containers with specific functionality; get automatic verification for allowed usage and an updated audit trail



4) Share data in a well-defined way (i.e., including usage policy and full provenance) and document any access
    a) for operational containers data can be accessed through an API using the OAuth2 protocol; optionally, access can be subject to a charge and is billed automatically through a cryptocurrency
    b) containers can be shut down and distributed through images; for data access it is necessary to start the image (e.g., locally on your computer)

4 Technology

Based on the description of needs (section 2) and the previously described characteristics and design decisions (section 3), in the following the underlying technology used in Semantic Containers is outlined.

4.1 Cryptography

To unambiguously identify digital information Semantic Containers use hash functions extensively. Specifically SHA-256 is used to create a digest for data, policies, and containers. To explicitly assign data and metadata (like usage policy) to a user Semantic Containers provide mechanisms to digitally sign those hash values and provide automatic validation.

4.2 Blockchain

To make hash values or signed hash values immutable and verify this information independently those values are stored in a blockchain. An additional benefit of using a blockchain is to get a verified timestamp. For billing Semantic Containers use a cryptocurrency to transfer the monetary value between the two parties.

Ethereum was chosen as distributed ledger to store data as well as cryptocurrency because of the widespread use and maturity of the technology.

4.3 Semantics

At the core of Semantic Containers is the semantic annotation of data and semantic description of metadata using W3C standards:

- the usage policy clearly specifies what is allowed and not allowed with regard to the use of data
- the provenance documents the complete process from the data source to the current state
- the API description describes available functions in a container

4.4 Container

The above mentioned technologies are combined in a single self-contained package. As underlying technology Semantic Containers use Docker to also benefit from the existing infrastructure to store and distributed images. Semantic Containers are built in a way to be derived from a base container that can be extend with necessary functionality.

5 Use Cases

This section lists use cases we currently explore and partly implement during the funding provided by the Austrian Research Promotion Agency (FFG).

5.1 Data Donation

Participants donating data, provide data for free but at the same time they can control how their donated data will be used through defining specific usage rights. An additional benefit is the possibility to track donated data as well as derived results.

Examples for data donations:

- collect GPS data from your phone and support a study from the Vienna University of Economics and Business to evaluate the quality of route recommendations provided by Google Maps
- download step count data from your iPhone through Apple HealthKit and aggregate this information to show average step counts per day for all participants

5.2 Providing Data

Organizations that want to make data available either to other businesses or to the public can use Semantic Containers as light-weight and decentralized distribution platform. The provided functionalities include billing as well as tracking the use of the data.

Examples for organizations providing data through Semantic Containers:

- ZAMG (Austrian Central Institution for Meteorology and Geodynamics) will provide weather and seismic data through an Semantic Container API; requests to weather data are not free and subject to a fee
- EODC (Earth Observation Data Centre) will provide processed satellite images from the EU Copernicus program for given GPS coordinates with a 5-day update interval
- Semantic Containers can provide the technical infrastructure to fulfill a new “Payment Service Directive” for banks which are required to make account statements available to customers and transferable between institutions

5.3 Private-Corporate Partnership

Establish a data-flow between private citizens and corporations to allow individuals monetizing data while keeping their privacy and businesses to access personal data in a GDPR-compliant way.

Example for a private-corporate partnership:

- a group of people with diabetes collects and anonymizes their blood sugar level; these data are in demand by the pharmaceutical industry to comply with new regulations regarding real world evidence (i.e., is the clinical evidence regarding the usage and potential benefits or risks of a medical product derived from analysis of real world data)

6 Final Remarks

In this white paper we envision to provide a stable and simple data exchange mechanism between two parties.

You can find the latest version of this document on https://www.ownyourdata.eu/semcon.

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Please don’t hesitate to contact us with any comments and feedback via semcon@ownyourdata.eu.