PeTwin: An ontology-supported data access for petroleum production digital twin

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Abstract

A digital twin is a system framework tightly attached to a physical production plant conceived for monitoring the operation in real time. This framework integrates data from distinct sources and supports data analytics and predictive evaluation of the petroleum flow and the maintenance schedule. The scenario's difficulty includes multiple data suppliers, diverse data sources and platforms, heterogeneous data types and formats, data or unit transformation needs, and multifaceted data semantics. These requirements demand an innovative semantic solution for data integration and processing in the digital twin environment. The PeTwin project looks to define the best practices and software solutions for the development of digital twins for petroleum production plants. The project's central objective is to deal with the semantic complexity of the information and offer a functional framework for machine learning and data analytics to support engineering daily operations in petroleum production surveillance. We have developed a network of BFO-based domain ontologies, an associated knowledge graph, and an application layer that implements the semantic treatment of information in a real scenario of petroleum production wells.

Keywords

digital twin, ontology, semantic data access and integration, petroleum production

1. Introduction

The information that feeds a modern oil-field digital twin integrates temporal series and static data, configuring a complex scenario for data analytics. The data is usually spread across many applications from several service companies that perform specific tasks during operations. These systems exchange data in distinct layouts, sometimes in proprietary formats. Even when accessed in open formats, an integrated digital twin requires uniformization in data meaning, formats, units of measure, the scale of analysis, and interval of time associated with the track of data provenience. The integrated operation center receives these data hand-labeled with their source and meaning and analyses them to support short-term decisions.

The PeTwin project is a 4- year (2020-2024) joint cooperation between Oslo University and UFRGS, with the participation of Libra Consortium (Brazil), Equinor (Norway), and Shell (Norway) that looks to define the best practices for the development of digital twins for petroleum production plants and for offering data analytic methods based on machine learning.

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2. The ontology for petroleum production plant

One contribution of the UFRGS team to the project was developing a well-founded domain ontology to document the meaning and logical restriction of the assets and processes involved in petroleum production and facility maintenance, structuring the framework for the semantic interoperability of data operated by the digital twin. We proposed the O3PO – Offshore Petroleum Production Plant Ontology [1], a network of independent domain ontologies dealing with a specific part of the petroleum production process. The ontology development started with an extensive survey of existent standards and ontologies in the petroleum industry domain. Our research includes the resources of ISO 15926; the integrated data platform from the OSDU - Open Subsurface Data Universe Forum [2]; the standard glossaries of the Professional Petroleum Data Management (PPDM) What is a Well? [3] and What is a facility? [4]; the interoperability standard PRODML [5]; and the equipment specification of CFIHOS [6].

We followed the analysis of these resources by a sequence of interviews with petroleum industry professionals from subsea, reservoir, flow maintenance, production, and integrated process monitoring areas. The interviews produced a list of digital twin software functional requirements and raised the terminology adopted for system and data labeling that drives the domain ontology usage. The whole ontology network followed the same building methodology. It specialized the Basic Formal Ontology (BFO) top ontology, which guarantees a common conceptual basis for integration and makes easy alignment with previously developed BFO-derived domain ontologies. The ontology formalizes the logical definition and textual documentation of each entity representing the production plant installation assets, including their qualities, domain of qualities, relations, and associated dependent entities. We manually created a knowledge graph expressing all instances and relations among them, such as pipe connections, installation sets, and components.

The network of ontologies provides the semantic framework for the whole digital twin architecture and software applications with several semantic capabilities. A set of OWL files that describe the ontology entities, the knowledge graph of ontological relations among ontology instances, and the mapping component that connects these two components with other applications compound the semantic framework. We applied this framework for several tasks, such as information retrieval in the historian system, extracting contextual information about the production plant installation, and connecting the assets with P&ID (piping and instrumentation diagram) to explore the oil flow data in the diagrams. This usage led to the development of in-house applications and the adoption of cloud digital twin solutions.

One in-house solution, focused on the visual exploration of assets, uses the embedded knowledge in the knowledge graph to find the appropriate time-series data in a historian system while also using it to provide more context to the system user. The user selects the ontology entities, and our knowledge graph application retrieves the data associated with these entity instances directly from the data storage, such as well names, their parts and types of properties, and the references to the time series in the historian system. We have conceived the whole solution as a microservice architecture, in which the components play a specific task customized to the environment and software platform, as shown in Figure 1 (a). This approach allows the easy adaptation of the solution for other ontology-based tasks and platforms. Figure 1(b), extracted from [7] depicts the application interface with its main functionalities.

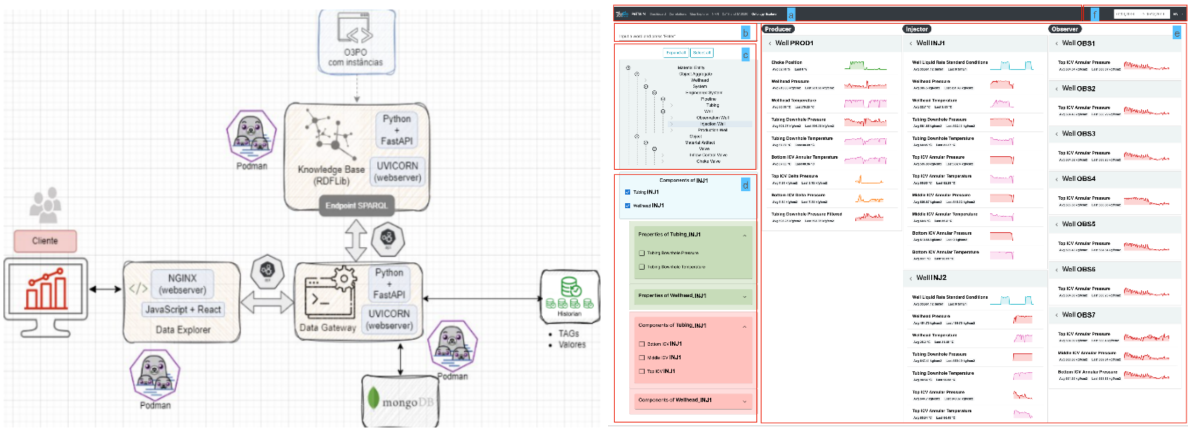

Figure 1: (a) The functional-view architecture of the PeTwin framework. (2) Main interface of the ontology explorer [7] application providing entity selection, search box, hierarchical navigation in the ontology taxonomy, exploration of components and properties of selected instances, time-series plots, and timeline filter.

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