Developing Monitoring Ontologies for Embankment Dams

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Abstract

This publication aims to present the progress made in the first author's PhD thesis: monitoring ontologies for embankment dams safety control. These ontologies comprise sub-domains such as monitoring and site inspection (described in this extended abstract), general information (such as dam's location, stakeholders information, compliance with regulations, etc.) and the geometric configuration of the dam's body elements, materials, and geological-geotechnical properties. Ontologies are being developed with Protégé software, which uses reasoning to infer new knowledge. They are integrated into GraphDB software, and together with externally connected databases (containing semantic and metric data), configure a knowledge graph. This data will be integrated into a simplified system (platform) developed to visualize and manage information regarding the safety and maintenance of an embankment dam. The platform will update the corresponding BIM-based digital model and include an alert notification system, which will trigger appropriate safety procedures in response to the analyzed data.

Keywords

Ontology, embankment dam, observation, monitoring, safety, knowledge graphs, linked data integration

1. Introduction

The design, construction, operation, and maintenance of embankment dams are activities of great complexity and responsibility that require efficient collaboration and clear information exchange to reduce time and waste, thereby optimizing workflows and ensuring sustainability. Emerging technologies like digital twins and the semantic web are paving the way for improved decision-making, but are still incipient in dam engineering. A significant research gap in the domain of dams is the lack of a standardized, specialized terminology dictionary and a universal language that eases data interoperability and understanding by humans and machines [1–4].

Drawing from developments in buildings and linear infrastructures (roads [5–8], tunnels [9], and bridges [5, 10]), ontologies are key tools that provide semantic frameworks for standardizing concepts, interpreting meanings, enabling reasoning, and extracting new knowledge from systems called knowledge graphs (that relate ontologies with "loose" data) [11]. The development of these formal knowledge models will boost the digitalization and data integration of embankment dams, laying the foundation for more informed decision-making regarding their entire life cycle, in particular, operation and maintenance.

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2. Methods and Results

Ontologies are being developed according to the methodology proposed by Noy et al. [12], using Protégé software in OWL (Web Ontology Language). It is based on a triple-based model, following an RDF (Resource Description Framework) syntax.

Although the developed ontologies address a broader domain of embankment dam safety, this publication focuses primarily on a sub-domain concerning the monitoring and site inspection of zoned earth-fill dams, with particular emphasis on the definition of the observation plan. It is noteworthy that other sub-domains are being developed to expand the ontology network around the common theme of dam safety: general information on the dam (e.g. location, stakeholders, class and classification according to the Portuguese Dam Safety Regulation — RSB [13], etc.), the geometric configuration of the dam's body elements, and materials and their geological-geotechnical properties.

The new ontology will include some of the classes, object and datatype properties from existing ontologies, such as SAREF [14], SAREF4WATR [15], SSN&SOSA [16], DCTERMS [17], GEO [18], OM2 [19], SKOS [20], when applicable. However, some specific terms related to dams, specifically embankment dams, are still unavailable and will be included in this new Monitoring and Observation Ontology for Dams (MOOD) (Figure 1).

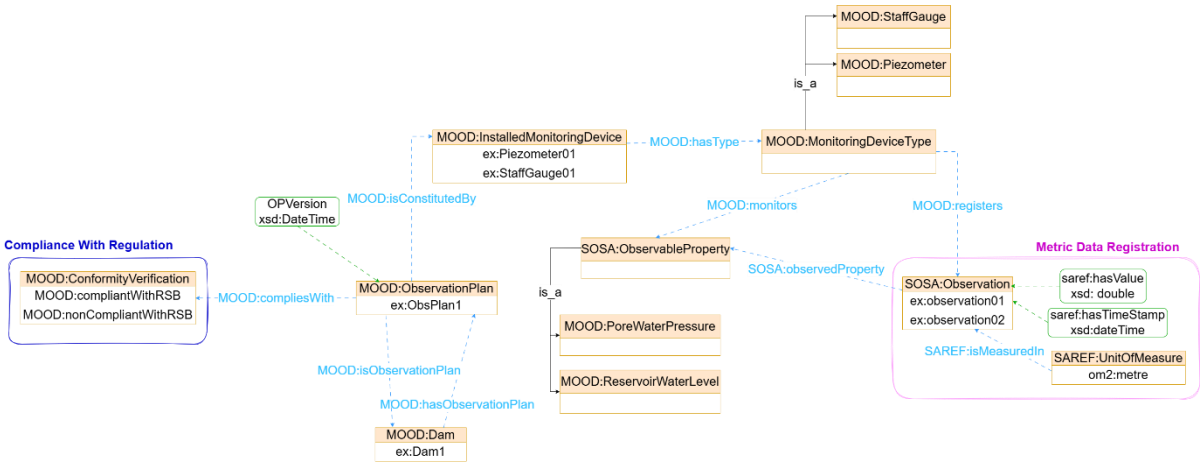

Figure 1: Excerpt from the Monitoring and Observation Ontology for Dams (MOOD). Source: First Author.

Ontologies will be validated by integrating them into a knowledge graph (GraphDB), enriched with external data sources related to an actual embankment dam. Due to the nature of this type of infrastructure, two types of data will be approached: semantic and metric data (collected either remotely or manually). Semantic data will be extracted from the BIM model, whereas observational data related to site inspections will be sourced from relational databases (PostgreSQL). The knowledge encoded in the graph will be accessed and evaluated through SPARQL queries. The ontology's scalability allows for the development of higher levels of detail in the future, enabling more precise and tailored assessments as the system evolves.

3. Conclusions

The presented study concerns part of a task to be developed within the scope of the first author's doctoral thesis. The created ontologies alongside a set of different types of databases (concerning semantic, metric and telemetric data) are to be integrated in a system (data integration at the system

level) that will allow interaction between the BIM-based digital model and the physical entity, including an alert notification system, configuring an embankment dam's digital twin.

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Declaration on Generative AI

During the preparation of this work, the author(s) used Grammarly and ChatGPT to check grammar and spelling and paraphrase. After using these tools/services, the authors reviewed and edited the content as needed and take full responsibility for the publication's content.

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