Linked Data Approach to Water Resources Management of Hydropower Reservoirs

M Damova¹, E Stoyanov², M Kopchev³, K Kuzmanova⁴, S Natali⁵
¹ CEO, Mozaika, Sofia, Bulgaria
² Senior Architect, Mozaika, Sofia, Bulgaria
³ Software Developer, Mozaika, Sofia, Bulgaria
⁴ Project Manager, GISolutions, Sofia, Bulgaria
⁵ Senior Analyst, SISTEMA, Vienna, Austria
E-mail: mariana.damova@mozaika.co

Abstract. The exploitation of hydropower reservoirs involves daily water resources management. Water resources managers consult periodically collected detailed data about the condition of the hydropower reservoirs, water economic data, meteorological data and forecasts, geographical and geospatial information about the water reservoirs and their contingent environment. These data are usually scattered and looked at one by one per category. Moreover, satellite data have not been typically involved in this process. We propose a linked data approach [1] to create knowledge value chain for the needs of hydropower reservoirs exploitation, based on semantic integration of earth observation data with spatial information of GIS, symbolic, numerical data and domain knowledge. We demonstrate on the example of water balance calculation for dams and cascades how satellite data and in-situ measurements are being mixed with other data, apply neural networks [2] to forecast water levels, water volumes and other characteristics based on historic data. We show how the results of the forecasts interoperate with the linked data infrastructure, how dangerous situations for the contingent areas of the water reservoirs can be identified and how signals about risks of dam overflow and hence about the water quantities available for discharge can be provided.

1. Introduction

The exploitation of hydropower reservoirs involves daily and strict water resources management that addresses the need of water resources managers to know the status of the hydropower reservoirs and their nature environment in order to plan water discharge activities and make informed decisions for maintenance, routine exploitation and emergency situations. They consult heterogeneous data that are scattered and usually looked at one by one by human experts in order to analyze, summarize the evidence, and come up with the adequate conclusions and action plans. To make this process easier and more effective, information and decision support systems that allow the inspection of the different sources of information, including satellite data, from a single interface and provide analytics based on numeric data from different sources have been put in place [3],[4],[5]. However, capabilities of federated and integrated representation of spatial, numeric, symbolic data, images and metadata in their interconnectedness that can benefit from logical and numeric reasoning and operate in an open, easy to maintain, update and rely on information infrastructure of interoperable heterogeneous data have not been put in place yet. Linked data technologies [6] offer an optimal standardized framework to deal with this issue, as they allow easy data integration, resource economy and seamless extendibility of the required information. These capabilities break the data silos and enable the creation of a knowledge value chain converting the data into insight and providing a powerful instrument to help this domain of significant societal and environmental impact.

2. Linked Data Infrastructure

We propose a linked data [6] approach to obtain data interoperability between spatial information of GIS systems, remote sensing information, symbolic and numerical data, e.g. meteorological data and proprietary in-situ measurements and create knowledge value chain for the needs of hydropower reservoirs exploitation, based on semantic integration of earth observation data about meteorological elements with in-situ measurements and domain knowledge in an open, easily extendable and maintainable information infrastructure. The linked data information infrastructure employs a crafted for the purpose water management ontology built on top of INSPIRE Data Specification on Hydrography [7], that includes 127 semantic elements from GIS, satellite data, proprietary measurement data and domain knowledge. It allows interconnection of and logical reasoning over the introduced semantic elements and generation of additional relevant related facts that become available for querying. The linked data information infrastructure applies intelligence that mixes numeric with symbolic reasoning, and exposes the federated heterogeneous information in an easy to grasp manner, c.f. figure 1.
3. Forecast modeling

To calculate the forecast for single water balance characteristics we employ information from 6-7 satellite sources from ADAM [8], e.g. precipitations (solid and liquid), soil moisture, air temperature, skin temperature, vegetation index, and in-situ measurements of water balance characteristics, build CNN models [9] and generate predictions about the water level, the water volume, the inflow and the water equivalent of the snow stock based on historic data. The historic data are from ten years daily measurements of all quoted datasets. The produced forecast is for 30 days ahead, allowing to query and obtain results for single future days, for future periods of time and subsequently to compare the forecast values with the coming up real measured values. Experiments have been carried out for each characteristic of the water balance – water volume, water level, inflow, water equivalent of the snow stock over the three dams of Cascade Arda, e.g. Kyrdjali, Studen kladenec and Ivaylovgrad. The best MinMae score obtained has been between 1-5 mln m³ depending on the forecast feature and on the dam.

4. Querying and Alerting

The results of the forecasts are semantically integrated into the linked data infrastructure along with the in-situ measurements, the satellite data, the GIS information and the domain knowledge about hydropower reservoirs management, and made available for querying via GUI [10]. This enables users to query about different correlations of water balance characteristics and satellite data or snow stock information. For example, one can query about “the precipitations and the soil moisture when the water volume of dam Kyrdjali was maximal in the past 10 years”, and obtain figures and map view via the GIS [11] component of the application of the satellite data about precipitations and soil moisture for the date of the maximal water volume of dam Kyrdjali and the maximal value itself. One can also query about the “Snow cover, when the water level of cascade Arda was above 374.5 m”, and obtain results about the snow cover from the satellite data displayed on the map view of the GIS component, and its values for the date when the water level of the three dams of cascade Arda exceeded the amount specified in the query, etc. Except for integrating the forecast values into the semantic infrastructure, we incorporated control values for water levels that if exceeded present hazardous situation. Thus, the generated forecast values also predict upcoming dangers of dam overflow or risky water levels that can have harmful impacts on the contingent areas of the water reservoirs. When such a situation is detected, an alert is thrown and displayed on the GUI, so that the operating user gets warned about a risk of dam overflow and can make decisions about the water quantities to discharge.

5. Conclusion

The proposed approach has clear advantages with respect to non-semantic solutions and standalone GIS applications because of its ability to provide information in a way the non-semantic solutions are not capable of and because of its easy extendibility and maintenance because of the use of the standardized linked data.

Acknowledgement

This work has been carried out within ESA Contract No 4000122783/17/NL/SC

References

[1] http://linkeddata.org/
[2] https://adeshpande3.github.io/A-Beginner%27s-Guide-To-Understanding-Convolutional-Neural-Networks/
[3] https://mottech.com/%e2%80%8eirrigation-control-systems/
[4] http://www2.advantech.com/EDM/9F86F8b-893BDD-4518-8b6C-81FA494FE329/water.html
[5] https://www.arcgis.com/apps/Cascade/index.html?appid=414730116A3C4C119B80E89D1727AB74
[6] https://www.w3.org/standards/semanticweb/data
[7] https://inspire.ec.europa.eu/id/document/tg
[8] https://adamplatform.eu/
[9] https://adeshpande3.github.io/A-Beginner%27s-Guide-To-Understanding-Convolutional-Neural-Networks/
[10] http://service.isme-hydro.bg, http://isme-hydro.bg
[11] https://www.esri.com/en-us/arcgis/about-arcgis/overview