Addressing climate change preparedness from a smart water perspective

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ABSTRACT

Observing the world on a global scale can help us understand better the role of water and water resource management utilities in a climate change context that engage us all. The usage of machine learning algorithms on open data measurements and statistical indicators can help us understand the behavioral changes in seasons and better prepare. These are complemented by powerful text mining algorithms that mine worldwide news, social media, published research and patented innovation towards best practices from success stories. In this paper, we propose a data-driven global observatory that puts together the different perspectives of media, science, statistics and sensing over heterogeneous data sources and text mining algorithms. We also discuss the implementation of this global observatory in the context of epidemic intelligence, monitoring the impact of climate change, and the value of this global solution in local contexts and priorities.

CCS CONCEPTS

• Real-time systems • Data management systems • Life and medical science

KEYWORDS Climate Change Preparedness, Data-driven Decision-making, Water Resource Management, Smart Water, Observatory, Water Digital Twin, Deep Learning, Text Mining, Interactive Data Visualization

1 Introduction

In the present decade, Climate Change has become positioned as one of the world priorities, a global problem with great socio-economic impact. It has been in the focus of European and Worldwide strategies, rapidly changing priorities towards sustainability and environmental efficiency, transversely to most domains of action. The European Commission's Green Deal [5] is a good example of this, aiming for a climate neutral Europe in 2050, and boosting the economy through green technology over a new framework to understand and position water resource management in the context of the challenges of tomorrow [1]. In the context of the NAIADES project [3] we repurpose and customize the NAIADES Water Observatory, adding a measurements dimension to its text mining capabilities to allow for forecasts on, e.g., water level and temperature to complete the perspective on the impact of climate change for the preparedness both of water management utilities and users as in, e.g., smart agriculture. This will improve the climate change preparedness of water resource management facilities and local authorities in a global context, in particular in European regions where water scarcity or extreme weather events are predicted. The water-related climate change topics that we are already addressing include, e.g., water reuse, wastewater management, saline intrusion and groundwater contamination.

In this paper we will discuss our contribution to this cause, through the NAIADES Water Observatory (accessible at naiades.ijs.si) [12], focusing on water-related aspects, allowing the user to explore a combination of perspectives offered over layers of information sourced in statistics, historical measurements, multilingual news and social media to published science, weather models and indicators. It is also being used in the context of extreme weather events to analyze worldwide trends and best practices in water topics like, e.g., floods, landslide, and contamination [9], building business intelligence from the available open data in combination with data streams [11].

The NAIADES Water Observatory is not only contributing to the improvement of European sustainability in water-related activities and business intelligence but it is also providing an active role to local actors in improving together with municipalities and water resource management utilities the efficient use of resources [13]. This local perspective is especially important for providing information at the local granularity, which enables communities or municipalities to build solutions that are relevant for their specific cases.

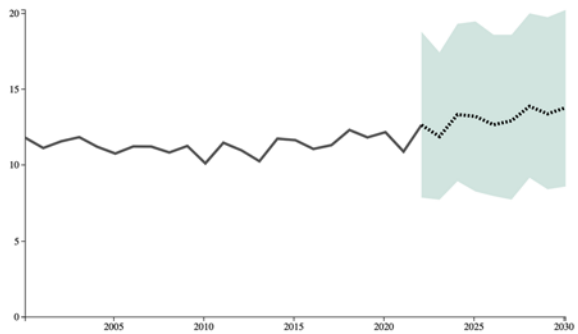

Figure 1: **Long-term forecast of 10 years (average per year) built on 20 years of data to understand the behavior of air temperature, water levels and temperature and the consequent changes within seasons.**

2 Understanding behaviors from data

In the era of Big Data where technologies and sensors are every day cheaper and more efficient, a wide range of useful measurements is available and can be used to forecast weather and water resource behaviors and to identify environmental trends with local granularity.

With the motivation to grasp a realistic perspective on the impact of climate change in the region of Carouge, Switzerland, we obtained 20 years of water levels and water temperature data (sourced by Meteoswiss Data Portal IDAWEB), and we were able to build a 10-year forecast that allows us to see a signal of the global trend.

For this aim, we have developed a Long Short Term Memory (LSTM) neural network, which is a type of Recurrent Neural Network, widely used for predicting sequential data. In order to optimize the performance and accuracy of the LSTM, we used some results from Differential Geometry and Chaos Theory such as Takens' Embedding Theorem, Shannon Entropy, Conditional Shannon Entropy, Markov Chains, etc. This theoretical support was key for obtaining the optimal number of timesteps [4] and to produce a long-term forecast aiming to observe the weather behavior across the historical data collected and a perspective on the future seasons based on the derived prediction, represented by the three parameters - temperature, humidity and rainfall - or the water levels in rivers, lakes and basins in the area determined by the geolocation provided by the NAIADES use cases. The time series of historical data in Figure 1 indicates that already the air temperature yearly averages are increasing, and this increase is predicted also for the next 10 years. Comparing our model with the Meteoswiss model for the area, the differences were minimal. To emphasize the changes throughout the year, we added a per year visualization (Figure 2), where one can compare the seasonal trends for the local weather and water parameters.

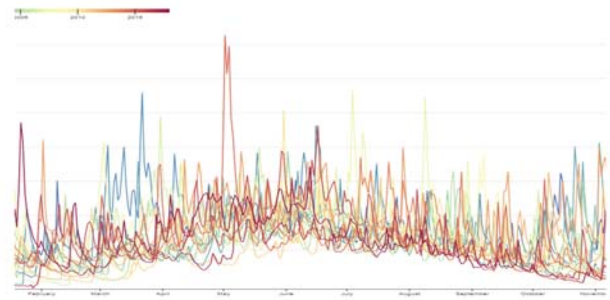

Figure 2: **The weather across seasons over the past 20 years distinguished by seasons, exhibiting high temperature periods earlier in the year.**

To further explore the relations of multivariate timeseries data, we have developed the State analysis tool [14]. With this technology we automatically abstract data as states of the Markov chain and transitions between them. This allows for ingestion of large datasets, and due to hierarchical clustering the data can be observed on several levels. This tool works especially well for observing long term behavior and exposing recurrent patterns. In the context of climate change preparedness, the aim was to better understand the reality of the seasons as defined by the weather parameters as well as the water level and temperature over the past 20 years. Depicted in Figure 3 are the transitions between seven states we can already depict in the municipality of Carouge, Switzerland and the surrounding area. Five of those states correspond to a passage between Spring-Summer and Summer-Autumn, and to Summer itself, characterized by the states indicating a high water temperature. With the impact of climate change in redefining seasons this tool can help to plan ahead, having in mind the granularity of the data that can be customized to predefined geographic regions where relevant water resources are located.

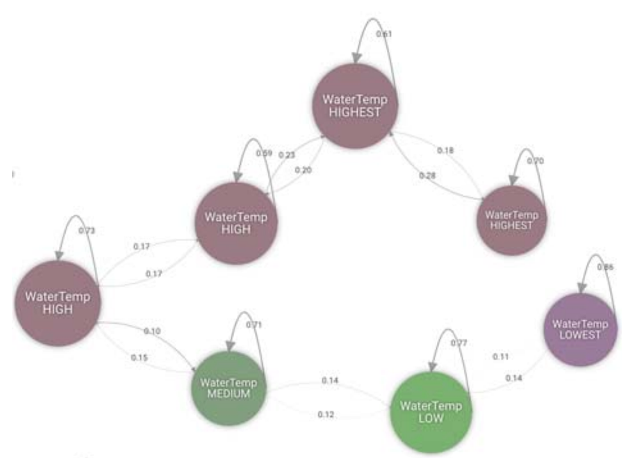

Figure 3: **The analysis of the impact of climate change on water levels and temperature across seasons using Markov chains**

3 Enrichment with local indicators

Water is fundamental to all human activity and ecosystem health, and is a topic of rising awareness in the context of climate change. Water resource management is central to those concerns, with the industry accounting for over 19% of global water withdrawal, and agricultural supply chains are responsible for 70% of water stress [10]. In 2015 the UN established "clean water and sanitation for all" as one of the 17 Sustainable Development Goals, aiming for eight targets to be achieved by 2030 [2].

To exploit the functionality for the customization at the level of local regional providers, news monitoring, and exploration of scientific research can be customized to observed problems, e.g., groundwater contamination. Moreover, ingestion of local indicators can be customized also. These agencies (e.g. Aguas de Alicante) are collecting data on their water resource management services to improve the customer satisfaction and optimize their system, aiming for a smart water [6] approach for the optimization of resources and means, often deploying intelligent systems close to the idea of a water digital twin [7].

Together with the municipality of Carouge, Switzerland, and with the water management utilities of Alicante, Spain, and Braila, Romania, we have collected open data from national data portals and environmental agencies with a regional granularity to be able to assess the comparative progress of regions through the visual data representation of indicators (see Figure 4). Through this interactive data visualization we can investigate the progress on a variety of topics (with three simultaneous parameters represented over a bubble chart) that are much relevant to the analysis of climate change, including water availability, reused and treated water, or water usage by populations and industry. With the appropriate combination of variables in comparison, the user can identify the most efficient regions over the country.

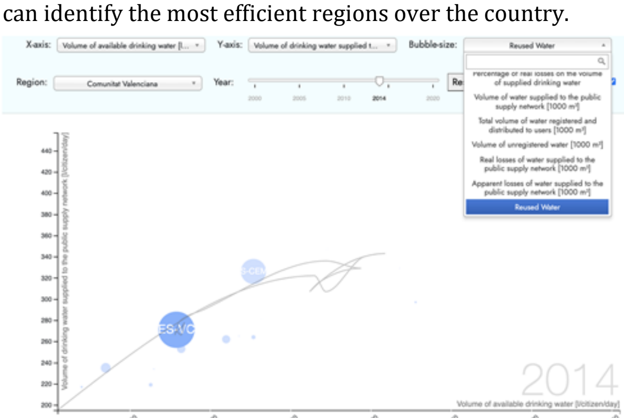

Figure 4: **The comparison of indicators in the Spanish regions across time**

To better understand the comparative progress of each region on the selected water-related topics, we also enable the representation of the time-series curves (see Figure 5) to identify transitions, peaks and other behaviors (per parameter in analysis) that are otherwise not seen in the bubble chart animation.

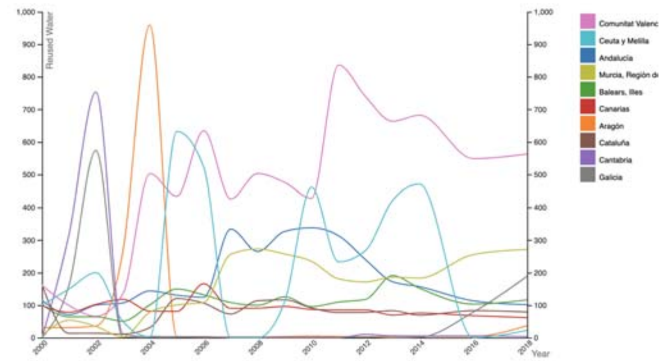

Figure 5: **The curves comparing regional indicators on water topics (as, e.g., reused water in Spain)**

4 Knowledge extracted from news, social media and scientific research

The NAIADES Water Observatory also allows for a news monitoring perspective with global and local coverage on topics like, e.g., water scarcity and water quality. It is particularly relevant in the surrounding regions of the water resource management agencies, but also at a worldwide level recurring to its multilingual capacity to access success stories and best practices form similar scenarios happening worldwide. This is based on the Event Registry news engine [8] that collects over 300 thousand news articles daily in over 60 languages. In the past 3 months we were able to capture almost 33 thousand articles relating both with water and with the climate crisis, 1500 of them happening in Spain and relating to concepts such as, e.g., draught, wildfire heat wave, irrigation and extreme weather.

Figure 6: **The combined perspective of multilingual news, social media and scientific research on water scarcity and extreme weather aiming to identify best practices and success stories**

This global system is also capturing the filtered Twitter feed on 10% of the signal, to identify posts related to heat wave and drought (see Figure 6).

The scientific research on climate change topics can bring an important complement in this context, providing success stories and best practices that can be extracted from the textual data, and explored with complex data visualization technology allowing the user to powerful Lucene-based queries over the article's metadata and to relate that research across time suggesting related topics (see Figure 7). These data analytics technologies are able to analyze simultaneously multiple time-series providing interactive exploration tools to understand trends in climate change research and water topics related to it.

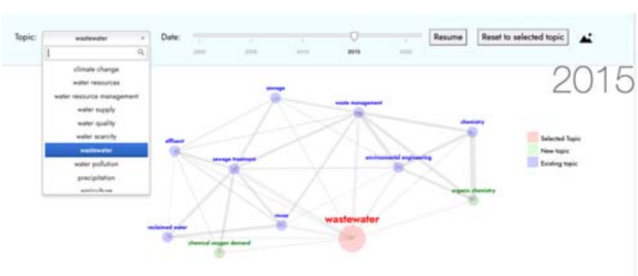

Figure 7: **The trends over time that relate to the topic Climate Change in the scientific literature**

5. Conclusions and further work

Adapting to climate change is an important topic for water management services, since their work is quintessential for the well-being of people. Understanding the seasonality changes and forecasting the availability of resources at the local levels is therefore crucial to enable relevant adaptation at the correct granularity.

Although the predictions are in accordance with IPCC's and Meteoswiss forecasting, this preliminary work needs to be extended with ingesting several other data variables and compared to the existing widely used models to bring more accurate insight specially for the weather data, but also the water-relevant resources.

ACKNOWLEDGMENTS

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REFERENCES

[1] A. Akhmouch, C. Delphine and P. G. Delphine Clavreul. Introducing the OECD principles on water governance. Water International, 43: 5–12, 2018
[2] V. Blazhevska. United Nations launches framework to speed up progress on water and sanitation goal. United Nations Sustainable Development, 2020
[3] CORDIS, "NAIADES Project". [Online]. Available: https://cordis.europa.eu/project/id/820985 [Accessed 1 9 2020].
[4] Costa J., Kenda K., Pita Costa J. (2021). Entropy for Time Series Forecasting. In: Slovenian Data Mining and Data. Warehouses conference (SiKDD2021)
[5] European Commission, "European Green Deal," 2019. [Online]. Available: https://ec.europa.eu/info/strategy/priorities-2019-2024/ european-green-deal_en. [Accessed 1 9 2020].
[6] C. Sun, V. Puig, G. Cembrano. (2020). Real-Time Control of UrbanWater Cycle under Cyber-Physical Systems Framework. Water: 12, 406.
[7] Di Nardo et al. (2018). On-line Measuring Sensors for Smart Water Network Monitoring. EPiC Series in Engineering. 3: 572-581
[8] G. Leban, B. Fortuna, J. Brank and M. Grobelnik, "Event registry: learning about world events from news," Proceedings of the 23rd International Conference on World Wide Web, pp. 107-110, 2014.
[9] M. Mikoš, N. Bezak, J. Pita Costa, M. Besher Massri, M. Jermol, M. Grobelnik (2021) Natural-hazard-related web observatories as a sustainable development tool in Progress, in Landslide Research and Technology, Springer, Vol. 1, No. 1, 2022.
[10] Our World in Data (2022). Water Use Stress. https://ourworldindata.org/water-use-stress. [Accessed 1 8 2022]
[11] J. Pita Costa (2022). Business intelligence built from open data. Water World Magazine. [Online]. Available: https://www.waterworld.com/water-utility-management/smart-water-utility/article/14234325/2203wwint [Accessed 1 8 2022]
[12] J. Pita Costa (2021). Observing water-related events to support decision-making. Smart Water Magazine. [Online]. Available: https://smartwatermagazine.com/news/naiades-project/observing-water-related-events-support-decision-making [Accessed 1 8 2022]
[13] J. Pita Costa, I. Casals del Busto, A. Guček, et al (2022). Building A Water Observatory From Open Data. Proceedings of the IWA 2022.
[14] L. Stopar, P. Škraba, M. Grobelnik, and D. Mladenić (2018). StreamStory: Exploring Multivariate Time Series on Multiple Scales. IEEE transactions on visualization and computer graphics 25. 4: 1788-1802.