APPLICATION OF DIGITAL SOLUTIONS IN THE WATER SECTOR

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Introduction

Instrumentation, Control and Automation (ICA) has become the 'hot topic' in the water sector, with more and more water utilities and companies paving the way in the monitoring, automation and optimised control of key processes in water and wastewater infrastructures. These key and enabling technologies are being viewed as a necessity in order to tackle the extreme water challenges we face globally due to the harmful effects of climate change. Additionally, the rapid advancement in the fields of Internet of Things (IoT), advanced sensors, data analytics, Business Intelligence (BI) and Artificial Intelligence (AI) – has led to a major transition of the water sector towards what is being termed 'Digital Water' or 'Smart Water'.

This transition gives the opportunity for the water sector to be transformed and optimally benefit from the implementation of these upcoming technologies. Some key building blocks in the digitalisation of the water sector are seen to be the following:

- **Increased deployment of instrumentation and sensors:** Water utilities have increased their monitoring and measurement campaigns a great deal, thereby leading to lots of data signals now being available for key process parameters within the entire water cycle.
- **Development of data–driven AI models to forecast and achieve optimal control:** With the widespread use of Machine Learning techniques and Artificial Intelligence algorithms, the water sector can now benefit from such methods with the possession of large datasets. Data–driven models can be developed for the purpose of forecasting key process variables, used to replace a failed sensor (soft sensors) and supporting process technologists in taking informed decisions to achieve (completely) automated process control.
- **Upgrading of the water utilities' data architecture and ecosystem that supports an automated (near) real–time monitoring and control:** In order to achieve real–time optimised control, the Process Automation and IT architecture may require renewal in order to achieve a plant–wide control, as opposed to conventional control loops that rely on a single process. Additionally, some external data sources, such as weather–related datasets, can be crucial information for the control of a water system. Therefore, a standardised architecture that can enable the eradication of data silos that exist between varying data sources and sectors, would greatly facilitate interoperability between systems.

Hence through Digital Water, which is steered by the above–mentioned key building blocks, the value of water can be combined with the value of data and knowledge which in turn can lead to the exploitation of water in a sustainable and self–sufficient basis through the use of innovative technologies. In order to achieve this, the water sector has begun its journey of transition, by implementing digitalisation and integration tools that will enhance the sector's stance in the smart cities initiatives, thereby paving the path for new innovative technologies.

FIWARE – A Cross–Domain Smart Solution Platform

As highlighted above, a key building block in the digital transformation of the water sector is the upgrading or development of the data and IT architecture that can support the next generation of internet services and enable cross–domain data–exchange to achieve real–time optimised control and automation.

A solution that is currently gaining momentum in the European context is FIWARE (www.fiware.org). FIWARE is an open source, smart solutions platform with an aim to support Small and Medium Enterprises (SMEs) and developers in the creation of smart applications in multiple sectors. FIWARE's intention is to become one of the main open and sustainable eco system for Smart City initiatives that can achieve easy cross–domain data exchange and cooperation, thereby eradicating data silos that hinder the progress of the development of next generation internet services.

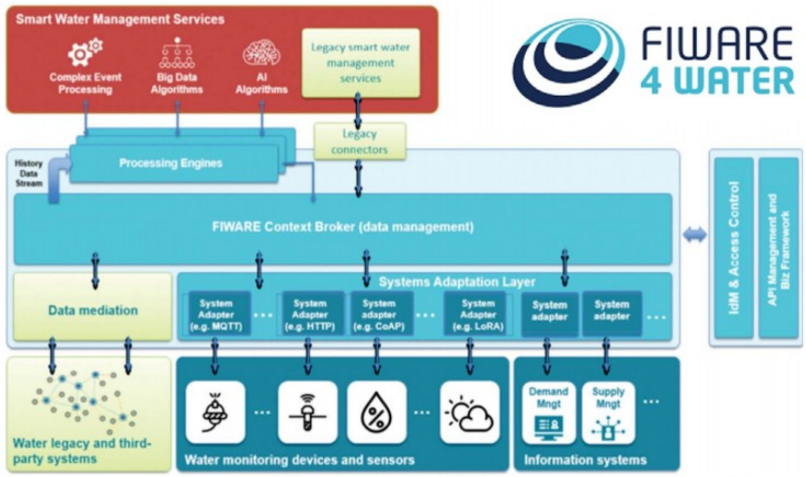
FIWARE has made considerable progress in other sectors such as Energy, Transportation or Telecommunication, with regards to the Smart Cities concept. However, in the water sector very little progress has been made until now in the development of smart applications using FIWARE that are interoperable, standardised and promoting cross–domain cooperation.

Therefore, through a directed call by the European Commission in 2018, five sister projects were initiated to introduce the concept of IoT compliant approaches for the water sector. The projects are Aqua3S (www.aqua3s.eu), Digital Water City (www.digital–water.city), NAIADES, ScoreWater (www.scorewater.eu) and Fiware4Water (www.fiware4water.eu). The common component among the projects is to investigate and develop open source FIWARE compatible applications for the water sector. The five projects combined compose a synergy group called Digital Water 2020.

Fiware4Water – A Prominent Study in the Digital Water Transition

The Fiware4Water project intends to link the water sector to FIWARE through the demonstration of its capabilities within different stages of the water cycle. The demonstration cases include smart applications for raw water supply, drinking water supply, wastewater treatment and customer interaction. Within the project, the potential of its interoperability and standardised interfaces are being investigated for both water sector end–users (such as water utilities, citizens, consumers and cities) and solution providers (private utilities, SMEs and developers). More importantly, the project aims to also demonstrate how linking FIWARE within the water sector can be non–intrusive and integrate well with legacy systems.

A FIWARE–based architecture can bring major benefits for the water domain – such as bringing water intro cross–domain applications, using standardised interfaces, models and methods for interoperability, revealing the power of data and boosting innovation in the water domain. Fiware4Water tackles digital water challenges, by linking the physical and virtual worlds and providing technology enablers which simplify the generation of effective knowledge and deployment of personalised smart applications.



Structure of Fiware4Water with links to legacy systems (Source: fiware4water.eu)

Case Study – Intelligent Control for Wastewater Treatment in the Netherlands

Within the Fiware4Water project, KWR Water Research Institute together with Waternet, the water utility for Amsterdam and surrounding areas, are working on a demonstration project to achieve intelligent control of a wastewater treatment plant (WWTP). The Amsterdam West WWTP has a capacity of 1 Million population equivalent and serves the city of Amsterdam. The Process Automation of the WWTP along with the supporting IT architecture are in fast development in order to benefit from emerging digital transition and integration technologies. Additionally, Waternet is also investigating the upgrade of the control loops of the WWTP, by transitioning to a more plant–wide control using real–time data and external data sources that can feed process models.

In order to achieve plant–wide control, Waternet has transformed one treatment lane of the WWTP West into a research lane. Additional sensors measuring pertinent parameters have been deployed leading now to an increase in the available data signals. Data–driven control strategies can now be tested using newly developed AI models and data fusion techniques. The objectives of the research are to minimise nitrous oxide emissions (a strong greenhouse gas), energy use and sludge production while maintaining the effluent water quality targets. This contributes to the Waternet over arching goal of achieving climate neutrality.

Smart Applications – Towards Optimised Control and Automation

Through the development of smart applications, automated plant–wide intelligent control can be pursued. The smart applications comprise an automated data validation tool, soft sensors that accurately predict key process variables, a digital twin AI model describing the process behaviour and an AI control model that determines an optimal trajectory. All smart applications are being developed and tested in the designated research lane.

KWR Water Research Institute has developed a data validation framework for the Amsterdam West WWTP. A key aspect that must be considered prior to applying data–driven strategies and AI models is data quality. Data quality can be impacted by sensor faults, (sensor) calibration issues, fouling or obstruction of the sensors and connectivity problems occurring during the transfer of data between the sensors and actuators and Process Information Management System (PIMS). As a result, data quality checks and corrections are

WWTP Amst erdam West (Source: fiware4water.eu)

needed. Therefore, an automated Data Validation framework, which can be utilised as a data screening and correction layer before sensor data are fed into the smart applications has been developed. The framework can be integrated within the FIWARE architecture developed for the case study. As a first step, detection techniques are developed which rely on data–driven, statistical methods (univariate or multivariate) as well as dynamic process (model) constraints. The next step is the development and testing of correction techniques in tandem with the development of virtual sensors to estimate key process variables.

The Waternet team has already developed soft sensors to estimate key process variables of the WWTP. The first soft sensor replaces failing aeration flow sensor readings. The soft sensor is an AI tool that estimates the individual aeration flows to each of the seven aeration tanks, based on one accurate aeration flow sensor, the header pressure and valve positions. This soft sensor is crucial to quantify the energy reduction possible through optimal control. The second soft sensor developed is the prediction of influent flow of the treatment plant. Two AI models were trained and predictions performance was compared. The prediction horizon of the influent forecast model is 75 minutes with a sliding time horizon.

Waternet also developed a digital twin for the WWTP which describes the behaviour of the treatment plant. This AI model estimates the state of 23 outputs and has been linked to an AI control model. The control model, which is based on reinforcement learning, determines the optimal control settings based on a reward system that includes energy use and nitrous oxide emissions. Once all remaining new sensors have been installed and sufficient data from the research lane have been collected to train the control model, the latter will be deployed and validated. Currently, the AI model has been successfully tested in other treatment lanes of the WWTP. The process automation system has also been modified, enabling the capability to use the setpoints determined by AI control model.

Linking Smart Applications with Fiware4Water Architecture

Through the Fiware4Water project, the smart application(s) developed for the case study will finally be integrated within a FIWARE architecture, while preserving the integrity and functioning of the legacy system. The Distributed Control System directly communicates with the sensors installed in the research lane and the data can be accessed through the PIMS.

This legacy system can then communicate with the Fiware4Water architecture, which is now being integrated. All communications within this architecture are conducted using interoperable (smart) data models and APIs. The potential of FIWARE for controlling a WWTP alongside the existing legacy systems will be demonstrated.

Conclusion

Instrumental, Control and Automation are key elements in the digital transformation of the water sector. With the increase in instrumentation deployment, development of data–driven AI models and upgrading of water utilities' IT and data architecture, automated plant–wide control is now in reach. Additionally FIWARE can accelerate the transition of the water sector to optimally benefit from such key technologies and in ensuring cross–domain cooperation (e.g. with energy). Moreover, with FIWARE being open–source and having a strong commitment to standardisation and interoperability of its solutions, countries such as India can greatly benefit from its implementation. With India's booming IT industry, development and implementation of innovative solutions to solve India's water challenges will benefit greatly from utilising FIWARE's ecosystem supporting the fast implementation of smart applications.

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About

KWR

KWR Water Research Institute, based in the Netherlands, is a leading international research institute operating at the heart of an engaging network of partners who collaborate to co–create science based, tailor–made solutions for local problems in the water–energy–food nexus. One of the areas that KWR is leading in is Hydroinformatics, with specific expertise in Digital Water and Instrumentation, Control and Automation. KWR is currently supporting the Indian water sector by exploring opportunities to apply the knowledge and skills gained from the Fiware4Water and other smart water management projects to assist in shaping a water–wise India.

To know more about the contributor of this case study, you can write to us. Your feedback is welcome and should be sent at: deepak.chaudhary@eawater.com.