DATA ACQUISITION IN A COMBINED SEWER SYSTEM

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1. CONTEXT

Urban water management involves different processes in order to carry out the functions of the water cycle final part. These processes are collection, evacuation, treatment and control of waste and rain water.

In order to reach the above mentioned objectives an integrated urban drainage management is fundamental at which an advanced, effective and sustainable sewer network performance is got.

A Remote Control System is composed by the monitoring and the remote control:

- Monitoring allows to know the network state in real time. That means that all the information related with the sewer network dynamic performance is known: rainfall, water lever and flow rate in the network, quality parameters, etc.
- Remote control allows to operate the system elements to modify the flow conditions. The control on the system can be done by an operator from the control centre or by control strategies previously designed.

Barcelona's combined sewer system is a good example of an advanced sewer network management. Its Remote Control System has sensors distributed in the network like water level sensors and rain gauges and it has different actuators as well, such as gates, valves, pumping stations and detention tanks. In Barcelona, the Remote Control System is working since 1992 and nowadays there are about 20 rain gauges, more than 100 water level sensors, 23 gates, 11 pumping stations and 5 storm water detention tanks on operation. And the number of actuators and sensors is increasing

Data measured by the sensors is collected and stored by the PLC (Programmable Logic Controller) placed near the sensor or actuator. Data is sent to the main computer, in de control centre, by a communication network which uses special telephonic lines or radio waves. Once the data arrives to the control centre it is performed with the SCADA (Supervisory Control and Data Acquisition System) so the operator has an interface where the data is displayed.

Finally, data is stored in a relational data base. It is used to centralize all the sewer network operational uses such as rainfall and water level reports, actuators performance reports, network access control, works and incidents occurred in the network, etc.

2. METHOD

An innovate project which is on development is CORAL (Sewer System Optimal control). In this project a new software is being developed in order to determinate the best control strategy for actuators of the sewer network in general. It takes into account the sewer network itself, with the data from all its sensors and devices, the waste water treatment plant and the receiving media quality. This paper explain with detail this system.

This paper describes this tool to aid in the analysis and design of combined sewer networks. Complex drainage systems include actuators, like flow-diversion gates and detention tanks, which should be optimally controlled in order to minimize flooding and combined sewer overflow (CSO), through these optimisations volume to waste water treatment plants (WWTP) is maximised. CORAL is a tool able to model a combined sewer network, simulate rain events, calculate actuators optimal policies reproduce past rain events and calculate different balances for all model elements.

To use CORAL in a complex urban drainage systems we need to work in two ways. First of all, it requires infrastructure, i.e. construction of detention tanks, flow-diversion gates, sluice gates, pumping station, etc. Secondly, it requires the installation of telemetry and supervisory control system. The telemetry system includes rain-gauges, flow or level meters (limnímetres) and quality meters distributed in main sewers and critical points of the network. The supervisory control system includes not only the controller command, but also the computation on control strategies to be applied in a complex sewerage system. In order to optimise the system performance.

This system works in real time, receiving the dates from the SCADA, searching the optimal solution and sending to the actuators, pumps and gates, this orders. To secure a good operation is necessary to have a good communication system, and is basic the good functioning of communications. CORAL is preparated to work with some faults of communications, but when a certain numbers of sensors and gates can not communicate with the control centre, CORAL must be automatically deactivated and we must regulate with another kind automatically control.

An operational model of an urban drainage system is a set of equations which provide a fast approximate evaluation of the hydraulic variables of the network and its response to control actions at the gates. This type of model is useful for the computation of optimal strategies, because it makes it possible to evaluate a large number of control actions in a short computation time. This type of model is usually known as a “conceptual” or “transfer function” model [3] and [4] it is also known as virtual-reservoir model [5].

The sewage network is modelled through a simplified graph relating the main sewers and set of virtual and real reservoirs. A virtual reservoir is an aggregation of a catchment of the sewage network which approximates the hydraulics of rain, runoff and sewage water retention thereof. The hydraulics of virtual reservoirs are linearised so that, in discrete time:

$$x^{k+1} = f(x^k, u^k, w^k)$$

where:

u represents a vector of control variables related to gate positioning (e.g. flow through the gate), x is a vector of observable states: stored volumes in reservoirs (real and virtual) and flows (or water levels) in main sewers, w is a disturbance vector containing rainfall intensities in the different catchments, f is a linear function expressing the mass balance of rain intake, sewer flow and reservoir volumes in the network. Its structure depends on the topology of the network and its parameters must be estimated using real data from the sensors installed. Finally superindexes k indicate time intervals.

We can use this simple equations, because we recalibrate in real time the parameters of the net.

In the next figure we can see an schema of CORAL:

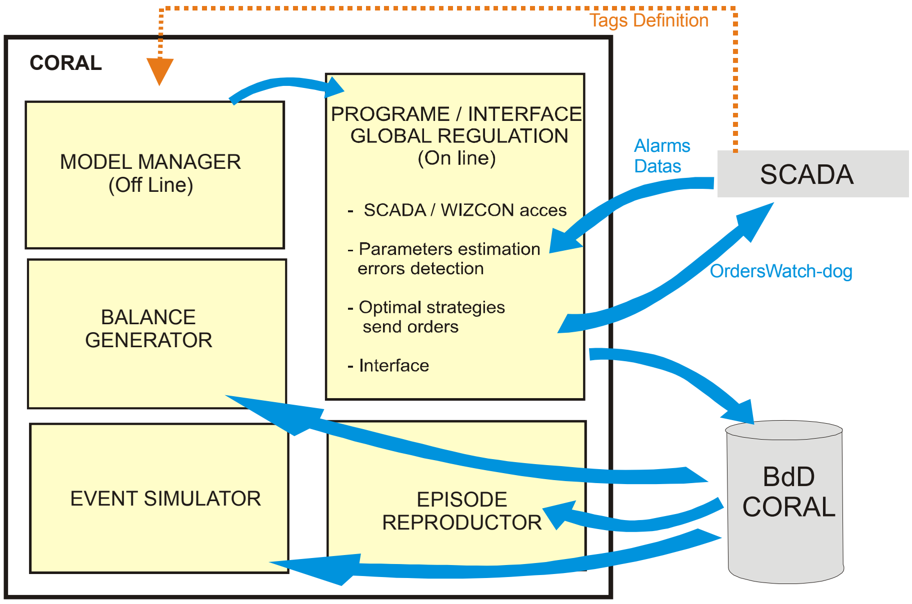

Figure 1. CORAL schema

The different parts off the application are:

- MODEL MANAGER

The model manager is a graphical user interface that manages the construction of an hydraulic model. It is also in charge of the model validation and the optimiser equation generation.

- PROGRAMME/INTERFACE

This module connect the application with the SCADA, received dates in real time, calculate the optimal strategies and send the orders to actuators. This module is connected with the Model Manager with an intermediate Data Model Structure. The next figure shows an example of Barcelona Sewer System. With this interface, the operator can control in real time the actions of CORAL.

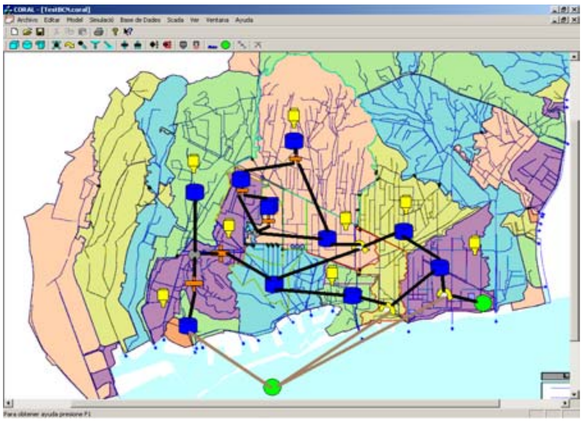

Figure 2. CORAL Interface example

- EVENT SIMULATOR

The event simulator simulates a hydraulic model with a certain rain. It must perform the following tasks: reading the rain intensity data from the CORAL data base, generating rain equations according to rain and model data, launching GAMS (the optimiser used) to optimise the control variables and compute model dynamics, collecting GAMS output and generating the model equations initial point for the next simulation step.

- EVENT REPRODUCER

The event reproducer reads data from an existing simulation and animates the model in order to show a pseudo-dynamic evolution of the sewer network. See in Figure 3 an example window of an event in reproduction mode. Note that levels in each tank are indicated by their coloured level that can be configured for each tank. In fact all active and passive elements can be animated but the end user can set up which elements will be animated.

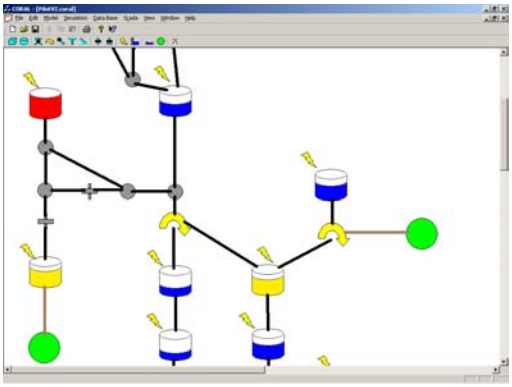

Figure 3. CORAL event reproducer

3. RESULTS

With the objective of reducing flooding and CSO and in order to take full advantage of the storage capacity of the urban drainage network and the treatment plants, a collaborative project for the implementation of the study of global control in the whole Barcelona network is underway. An off-line prototype of the system has been recently developed and tested in a pilot catchment, including one water retention tank.

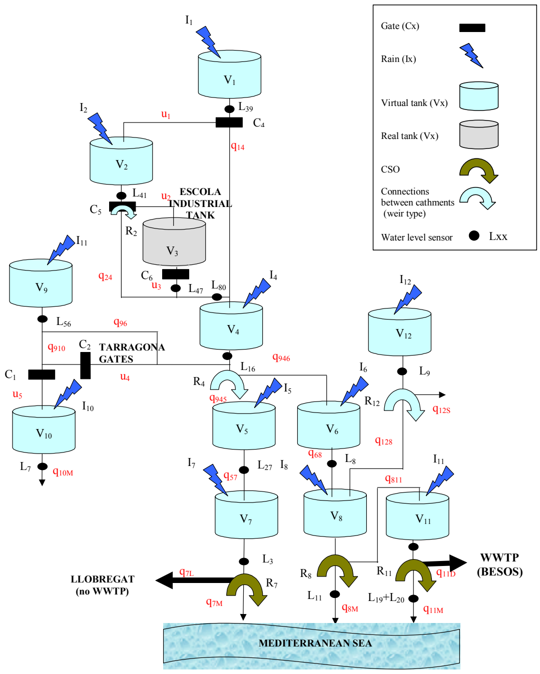

Figure 4. Barcelona test cathment model

The next illustration, shows the comparison of the total flooding, CSO and treatment plant volumes in three situations: without a detention tank, with the detention tank but using it as a passive element (inlet and outlet gates open at all times) and with optimal control simulated with real rain using CORAL off-line. The heavy-rain scenario corresponds with an average return period of 4 years and peak return periods of 12 years.

Heavy-Rain Episode (14/09/99)

	Passive no tank	Passive with tank	Optimized
Flooding, m^3	178647	138582	130293
Improvement, %		22,43	27,07
Treated Water, m^3	117375	132900	134307
Improvement, %		13,23	14,43
CSO	878817	867378	865509
Improvement, %		1,30	1,51

Figure 4. Results

4. CONCLUSIONS AND PRESPECTIVES

This paper presents a new simulation/optimisation tool, named CORAL off-line, for the analysis, study and control of sewer networks. This tool has been used successfully in a test catchments of the Barcelona sewer network. An on-line extension of CORAL will be implemented for realise the global optimal control of the complete sewer network of Barcelona. Nowadays we are connecting CORAL on line, just the pilot catchment and testing with real episodes.

The same tool is being used to model and study the localisation and benefits of retention tanks in for the Murcia sewer network.

This product can be implemented in another sewer system of other city, and also can be used in another kind of net. CLABSA is now developing a similar application for the drinking water net in Santiago de Chile.

5. SCIENTIFIC QUESTIONS

The principal answer of these application is that is possible to implement in real time. We are working in this way, and to obtain the same good results that we have off line, but in real time.

Another questions that actually we are working are:

¿Is it possible to work with another equations? ¿are they better?

¿Can we use sensors and actuators automatically errors detector?

6. REFERENCES

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