APPLICATION OF AGENT'S PARADIGM TO MANAGE THE URBAN WASTEWATER SYSTEM

M. Verdaguer, M. Aulinas, P. Escribano and M. Poch
Department of Chemical and Agricultural Engineering and Agrofood Technology, University of Girona
Campus Montilivi, Building PI, Girona, Spain
Laboratory of Environmental and Chemical Engineering, Technological Park of University of Girona
Building Jaume Casademont, Girona, Spain

Keywords: Multi-Agent System application, GAIA methodology, Urban Wastewater System.

Abstract: Urban Wastewater Systems (UWS) are complex and their management is a challenging issue. Each one of the three principal elements that compose the UWS (*i.e.* sewer system, urban wastewater treatment plant and the receiving water) has particular goals to reach. However, the elements of the UWS should be ideally considered together to perform an integrated management of the UWS. Nevertheless, this approximation, which seems to be necessary, is not easy. Each one of these elements is in practice managed by a different entity, which has specific strategies and functions to optimize that sometimes are opposed. In this communication, a well known agent-oriented methodology –GAIA– is used to model the relations that take place in the UWS. A prototype is implemented in Java using *Repast* in order to evaluate the possibilities of agent-oriented methodologies to model this kind of complex systems.

1 INTRODUCTION

Integrated management of Urban Wastewater Systems (UWS) constitutes a complex problem. When analyzing the water quality at river basin level, several sources of pollution are considered for their implication in the flow and the water quality of the receiving media (*e.g.* treated wastewater, runoff, rainfall water, etc.). These factors are intertwined and vary over space and time. They make the system very complex to model, to represent and to understand. The quality in the upper waters of the river can affect down waters. Hence, it is important to consider these elements as a whole (Erbe and Schütze 2005; Schmitt and Huber 2006; Fu *et al.* 2008).

Many other factors, apart from the ones directly affecting the quality of the receiving water, intervene in the UWS and have implications in the water quality at a river basin. As follows, some of the relevant ones are the population, weather conditions, industrial activities, wastewater treatment plants (WWTP) and sewer system elements.

The flow of wastewater in the UWS considered in this communication is depicted in Fig. 1. As shown, the UWS comprise a retention tank that permits to collect rainfall waters separately. A direct connection of this tank to the receiving water is also available, preventing excess of white waters entering the WWTP during extreme rainfall events. Each industry is connected to a tank that permits to store for some time its wastewater. Moreover, special pollutants can be diverted to a different tank, which can not discharge into the sewer system.

Each one of these elements fulfils one or several specific purposes, acting as an autonomous entity, but also interacting with other elements of the system. The final quality of the receiving media will depend on the good performance of these interactions, which are more than a simple aggregation of individual actions.

The consideration of the agent's paradigm and Multi-Agent Systems (MAS) in this context seems to be suitable. Agent-oriented approaches are good in representing the interaction between autonomous entities (from now *agents*) that hold specific individual *beliefs* but interact with each other in order to achieve a global goal (Sycara, 1998; Wooldridge, 2001). A state of the art in agent-based environmental applications is given in Cortés and Poch (2008).

Verdaguer M., Aulinas M., Escribano P. and Poch M. (2009).
APPLICATION OF AGENT'S PARADIGM TO MANAGE THE URBAN WASTEWATER SYSTEM .
In *Proceedings of the International Conference on Agents and Artificial Intelligence*, pages 497-500
DOI: 10.5220/0001660504970500

This work considers the use of agents' paradigm as a methodology to describe the relations that take place in the UWS. In section 2 the multi-agent system is briefly described, giving an overview of the agents involved in the system, their roles and the interaction between them. Section 3 describes the results of a simulation applied in a specific case study to manage the inflow at the WWTP. Finally, section 4 summarizes the conclusions.

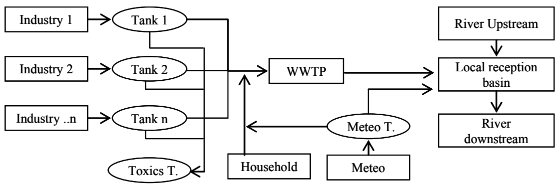

Figure 1: Physical elements of the Urban Wastewater System (arrows indicate the direction of the water flow in the system).

2 MULTI-AGENT SYSTEM

Multi-Agent Systems (MAS) are built on the basis of the agent's notion. Accordingly, MAS can be defined as a loosely coupled network of autonomous and heterogeneous agents that interact to solve problems that are beyond the individual capabilities or knowledge of each one (Sycara 1998; Jennings *et al.* 1998; Wooldridge 2001).

The agent-based model of the UWS proposed in this work has been developed using the GAIA methodology (Zambonelli et al. 2003). In GAIA the basis of the methodology is the good description of roles and protocols.

An example of one of the roles is shown in Fig. 2, in which there is a brief description of the role, together with the protocols, permissions and responsibilities.

As shown in Fig. 2, liveness and safety properties are very important in order to ensure favourable states for the system. During the working cycle, each of the liveness and safety values will be compared with the values provided by the sensors. The execution of the actions will follow a different path as a function of these values.

ROLE: Discharge of the retention tank of rainfall waters

Description : Discharge of rainfall waters from the retention tank into the receiving media or into the sewer system
Protocols & Activities: Check level. Calculate the difference between the measured value and the admissible maximum settled in order to prevent WWTP's overload. Inform discharge.
Permissions: Read level sensor
Responsibilities:
Liveness:
Value of the level measured in the tank ≤ Maximum value admissible level in the tank.
Safety
Maximum admissible level in the tank retention not to overload the WWTP

Figure 2: Schema for role "Discharge of the retention tank of rainfall waters".

2.1 UWS Agents

The MAS developed to describe the UWS elements and interactions comprises the following agents:

Meteorology Agent: develops tasks of information management associated with the collection of meteorological data from sensors, executes its model, and send the output to the receiver agent depending on the decision taken.

Household Agent: requests and receives data related to wastewater from households. Sends this data, properly treated, to the coordinating agent, and decides whether to send it or not to the council agent.

Industry Agent: requests and receives data from industrial retention tanks. Decides upon industrial wastewater discharges.

Coordinating Agent: requests and receives information from WWTP, households, meteorology and industry agents. Manages the information received in order to take a decision and prioritize industrial discharges to the WWTP. It is also in charge to prevent temporary overflows to the receiving media.

WWTP Agent: manages data from WWTP sensors and laboratory. According to this, decides on its own performance and operation, and sends its status to the coordinating agent.

Local Reception Basin Agent: corresponds to the receiving media. It receives values of water quality and quantity related to the discharge and from the river upstream. Accordingly, calculates the dilution capacity of the river at this point. It decides whether to put restrictions on the parameters for the next simulation cycle.

Basin Council Agent: coordinates the actions between different river sections. Take the final decision with regard to each fluvial section.

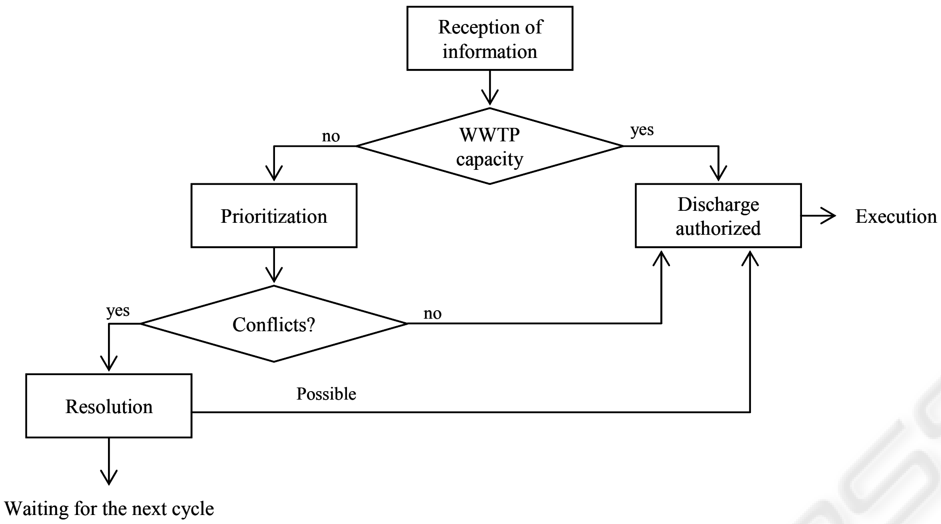

Figure 4: Schematic decision tree of the *Coordinating Agent.*

2.2 Agent's Communication and Protocols of Interaction

In the previous sections the type of exchanged information was described, whereas in this section the focus is on the flow of this information, that is, which agents can establish communication between them. It is important to notice that, whereas the flux of wastewater is unidirectional (see arrows in Fig. 1), the flux of associated information can be bidirectional or multidirectional (Fig. 3).

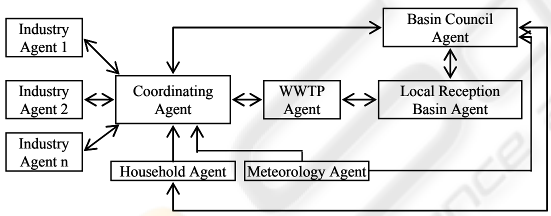

Figure 3: Agents' communication channels.

The accomplishment of the established safety properties for each protocol is a precondition for its initialization.

2.3 Agents' Decision Models

In the case study considered in this work, the key issue is coordinating the discharges from industry agents and take the decisions about their prioritization.

When deciding upon the authorization of an industrial discharge, first of all, the *Coordinating Agent* receives the information from *Industry Agents* concerning the flows and loads of industries' discharges. The discharges are kept in industrial retention tanks till the final authorization on whether or not to discharge to the WWTP is taken. The overall decision tree is depicted in Fig. 4.

The fundamental aim of the *Coordinating Agent* is to prevent that the contributions of wastewater into the WWTP overcome its capacity. For each cycle, it must be ensure that the combination of flows and pollutant loads do not overcome the maximum permitted thresholds.

3 SIMULATION OF THE MULTI-AGENT SYSTEM

In order to evaluate the use of the agents' paradigm to manage the UWS interactions a prototype has been implemented. The agent-based platform used is ***Repast*** (North et al. 2006). The implementation has been programmed in Java.

The first step of the simulation process consists in introducing the safety properties of each agent and reading sensor data from data bases. These values are compared and the result of the comparison is sent to Coordinator Agent.

The second step is the coordination of household and rainfall waters discharges with industrial wastewater discharges. Household discharges are prioritized in front of industrial discharges. The third step is the coordination of industries in order to prioritize their discharges. The main criterion is the assignation of specific time for each industry (as a function of the distance to the connected WWTP) in order to make the discharge and to check when the values surpass the safety ones. Hence, it is possible to guarantee that the arriving discharges do not surpass the WWTP safety values.

In Fig. 5 an example of the kind of results obtained are presented. In this case study, the objective is to maintain a value of the wastewater flow at the input of the WWTP as nearest as possible to the design flow of the plant, which guarantees its maximum efficacy. The system is capable to maintain near constant values at the input of the plant, optimizing the use of the tanks.

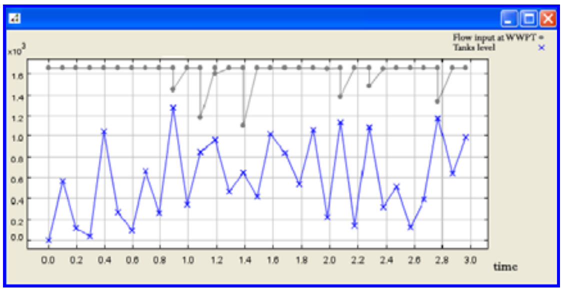

Figure 5: Evolution of WWTP inflow along the time.

4 CONCLUSIONS

In this communication it has been presented a preliminary prototype of UWS description using the agent's paradigm.

The system has been developed following GAIA methodology. Roles and interactions of agents considered to model the UWS have been described.

The prototype has been applied to manage the inflows at WWTP in order to minimize the variations, despite perturbations of different sources.

Results obtained, show that this approach can deal efficiently with the description and management of this kind of systems. Further work is needed to, in the future, identify some emergent properties at the level of the integrated Urban Wastewater System by means of more simulations and new scenarios.

REFERENCES

Cortés, U. and Poch M., 2008. Advanced Agent-Based Environmental Management Systems. Whitestein Series in Software Agent Technologies and Autonomic Computing. In Press.

Erbe V. and Schütze M. 2005. An integrated modelling concept for immission-based management of sewer system, wastewater treatment plant and river. Water Science and Technology 52(5):95-103.

Fu G., Butler D. and Khu S.T. 2008. Multiple objective optimal control of integrated urban wastewater systems. Environmental Modelling and Software 23:225-234.

Jennings, N.R., Sycara, K. and Wooldridge, M., 1998. A Roadmap of Agent Research and Development. Autonomous Agents and Multi-Agent Systems, 1, 7-38. Kluwer Academic Publishers, Boston.

North, M.J., Collier, N. T., Vos J.R., 2006. Experiences creating three implementations of the Repast Agent Modeling Toolkit. ACM Transactions on Modeling and Computer Simulation 16(1):1-25.

Sycara K.P., 1998. Multiagent Systems. AI Magazine 19(2):79-92.

Schmitt T.G. and Huber W.C. 2006. The scope of integrated modelling: system boundaries, sub-systems, scales and disciplines. Water Science and Technology 54(6-7):405-413.

Wooldridge, M. and Jennings, N.R., 1995. Intelligent Agents: Theory and Practice. The Knowledge Engineering Review 10(2):115-152.

Zambonelli, F., Jennings, N.R. and Wooldridge, M., 2003 Developing Multiagent sSystems: The Gaia methodology. ACM. Transactions on Software Engineering and Methodology 12(3):317-370.