An information system for the detection of water leaks in municipal water networks

Poulicos Prastacos IACM, FORTH Heraklion, Greece poulicos@iacm.forth.gr	Manolis Diamandakis IACM, FORTH Heraklion, Greece diamanda@iacm.forth.gr	Manolis. Kosmadakis DEYA Hersonissou Hersonissos, Greece ekosmadakis@gmail.com
Ioannis Dafermos IACM, FORTH Heraklion, Greece jdafermos@iacm.forth.gr	Yiannis Kamarianakis IACM, FORTH Heraklion, Greece kamarian@iacm.forth.gr	Yannis Pantazis IACM, FORTH Heraklion, Greece pantazis@iacm.forth.gr

Abstract

This poster provides an overview of an information systems that can assist the detection of water leaks in municipal water networks. The information system is GIS based and includes information on the water distribution network and other characteristics of the area, Water leaks are detected by acoustic sensors that are optimally placed in the network. The system has been developed for a pilot area in the municipality of Hersonissos in Crete, Greece.

Keywords: Water leaks, acoustic sensors, GIS, Hersonissos Greece.

1 Introduction

Municipalities around the world are faced with the problem that a significant amount of water is lost from leaks in the municipal water distribution network (WDN). In an era of increased water shortages there is a need to detect and repair leakages as soon as they occur. Most significant are not the occasional water leaks that can be easily detected but the water leaks that occur underground and can go undetected for a long time. Water leaks occur because the aging piping network is deteriorating, poor construction standards where used when the WDN was installed, the increased water pressure leads to pipes cracking, increased loads/traffic on the roads above the network and other geotechnical issues (even earthquakes) result in ground deformation etc.

It is difficult to estimate the exact amount of water lost through pipe-leaks. The results of an input-output analysis, the difference between water entering the system and water consumed/billed, cannot be considered only as water lost because of leaks. Consumed but non-billable water might result from leaks, but also from defected water meters and even the use of water for irrigating/cleaning public areas. It is acknowledged that the non-billable water accounts for 20-40% of the water entering the WDN and that at least half of that is attributed to water leaks. Most of the water lost through leakage is from leaks that occur underground and cannot be easily detected. There is a need, therefore, to develop technologies and information systems for detecting underground and non visible water leaks. Information systems can also guide maintenance workers to pinpoint the exact location of the damaged pipes and repair them.

2 The project

This brief paper describes an information system for the detection of water leaks using acoustic (noise) sensors and its implementation in a pilot area of the municipality of Hersonissos in Crete, Greece. The results reported are from the EPIRROH project funded by the Interreg Greece-Cyprus 2014-2020 program. Coordinator of the project is the Cyprus University of Technology and the project participants' project include the Water Board of Lemesos, Cyprus and in Greece the Foundation for Research and Technology-Hellas (FORTH) and the Hersonissos municipal water company (DEYAH).

As part of the project 100 acoustic sensors were installed in the WDN of a pilot area in Lemesos (Limassol) and 70 sensors in the WDND of a pilot areas in the municipality of Hersonissos (Mohos village). The sensors, detect the acoustic emission signals that occur when water escapes from the pipe and transmit these signals to the control center where they are displayed on a Geographic information system (GIS). Correlation of the acoustic signals of two or more neighboring sensors that are placed at a distance of about 100 meters (max distance for correlation depends on the pipe material) can pinpoint the exact location of the water leak. Information on water leaks and the technology for detecting them can be found in Lambert, 2002; Hunaidi et al., 2004; Blažević et al., 2005; Puust et al., 2010; Hamilton and Charalambous, 2012; Adedeji et al., 2017.

3 Location of the sensors

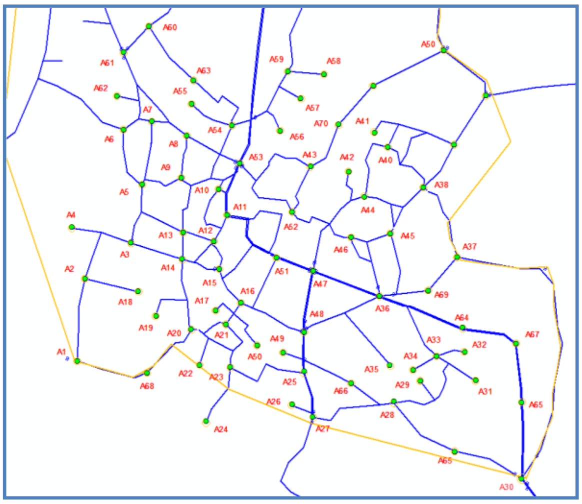
The leak detection sensors that are commercially available have limited range with respect their ability to "listen" the acoustic emissions from the leaking water. Depending on the material of the pipes this range is between 50 and 200 meters. Water utility companies therefore are faced with a limited resources problem and the decision process is a max min problem; they must maximize the area of the network surveyed by the sensors, while minimizing the expenditures for the acquisition and installation of the sensors. In the project described here, the number of sensors to be installed was determined a priori before performing an analysis and therefore the objective of the optimization problem for identifying the location of the sensors is to maximize the area of the network covered. In this optimization problem the inputs are as follows:

- The WDN network that determines the connectivity and the topology of the system,
- Information on the material and the age of the water pipes,
- Information on leaks that have occurred in the past,
- The range of the acoustic sensitivity of the sensors,
- The candidate positions for the sensors to be installed,
- The number of sensors to install.

The installation points of the sensors are determined using a variation of the Cognitive-based Adaptive Optimization (CAO) algorithm (Kosmatopoulos et al., 2007; Renzaglia et al., 2010). CAO is a stochastic approximation algorithm which randomly generates a large set of new candidate solutions from the current ones and then selects the best performing candidates. This process is repeated several times with decreasing level of stochasticity until it converges to a solution, which is nearly optimal. Our implementation for the optimal placement of water leak sensors relies on an auxiliary graph that encodes the shape and the topology of the water grid. The candidate positions are the nodes of the graph while the edges correspond to the actual pipes. We adapted CAO to operate on the discrete graph with the objective being to maximize the total covered length. A complete discussion of the algorithm developed is available in Pantazis, 2019. Alternative algorithms for selecting the location for placing the leak sensors can be found in Casillas et al., 2013, Christodoulou, 2015 and the references mentioned in these studies.

The location of the sensors is shown in Figure 1. Manual adjustment for the location of some sensors was also required.

Figure 1: Location of the water leak sensors



4 The information system

The usefulness of GIS integrated systems for managing the water distribution in urban areas has been recognized for a long time (Shamsi 2005; Christodoulou et al. 2006) and will be not elaborated further in this paper. The GIS system developed for Hersonissos includes information on the WDN, the location of the water leak sensors, the footprints of the buildings, the road system and water consumption (billable water) at the water metering locations. It was developed using ArcGIS (other commercial or open source GIS could support the existing functionality of the system).

The flow of information form the acoustic sensors to the GIS are as follows:

a) Acoustic signals are transmitted to the server of the company that has manufactured the sensors.
b) Using proprietary algorithms the signals from neighboring sensors are correlated to determine the exact location of the leak (HWM-Water Ltd, 2017).
c) The exact location of the leak is displayed on the GIS of the water utility company (DEYAH).

The GIS system developed for Hersonissos can be used for:

- Monitoring/displaying the location of the leaks and keeping a historical record of the leaks,
- Analyzing the WDN with respect its characteristics: when the system was put in place, material and other characteristics of the pipes and other components of the system, maintenance records etc.
- Analyzing the consumption of water at every metering location level and at the district/neighborhood level consumption at different time intervals (time interval depending on data availability from the water meters).

Additional functionality could be included if data are available.

5 The system for guiding maintenance workers

To assist the workers responsible for repairing the broken pipes to pinpoint the exact location of the leak an application that runs on a mobile/tablet was developed. It shows the WDN and the street network and guides maintenance workers to the location of the leak. The WDN can be visualized as vectors, but there are plans to develop an augmented reality interface that can show the underground location of different utilities (electricity, cable, optical fiber etc.). The existing system uses GPS for positioning since it is readily available. Additional and more precise positioning methods could be used in the future.

6 Conclusions

The information system can be used in any city that uses acoustic sensors to detect leaks. A significant consideration is of course availability of information on the WDN network, water consumption etc.. There are several areas of further research that could be considered in the future. These include analysis of historical data, WDN characteristics, water pressure data and water consumption to determine the districts in which leaks are more likely to exist as well as improved algorithms for analysing the audio signals for more accurate correlation methods to increase the reliability (avoid false alarms) and the pinpointing of the exact location of the leak.

Acknowldedgments

The research reported in this paper was carried out in the EPIRROH project that is funded by the Greece-Cyprus Interreg program 2014-2020.

References

Adedeji, K.B., Hamam, Y., Abe, B.T. and Abu-Mahfouz, A.M., 2017. Towards achieving a reliable leakage detection and localization algorithm for application in water piping networks: An overview. *IEEE Access*, 5, 20272-20285.

Blažević, M., Samardžić, I. and Kolumbić, Z., 2005. Leak detection in underground pipelines of municipal water distribution. In: *DANUBE Adria Association for Automation and Manufacturing International Conference on Advanced Technologies for Developing Countries*, 481-486.

Casillas, M., Puig, V., Garza-Castañón, L. and Rosich, A., 2013. Optimal sensor placement for leak location in water distribution networks using genetic algorithms. *Sensors*, 13 (11), 14984-15005.

Christodoulou, S., Aslani, P. and Deligianni, A., 2006. Integrated GIS-based management of water distribution networks. In: *Proceedings of the International Conference on Computing and Decision Making in Civil and Building Engineering*, Montreal, QC, Canada, 858-865.

Christodoulou, S.E., 2015. Smarting up water distribution networks with an entropy-based optimal sensor placement strategy. *Journal of Smart Cities*, 1(1), 47-58.

Hamilton, S. and Charalambous, B. eds., 2013. *Leak Detection*. IWA Publishing.

Hunaidi, O., Wang, A., Bracken, M., Gambino, T. and Fricke, C., 2004. Acoustic methods for locating leaks in municipal water pipe networks. In *International conference on water demand management,* Dead Sea, Jordan, 1-14.

HWM-Water Ltd, 2017. PermaNet: Web Dedicated software for the PermaNet product range, Cwmbran, UK.

Kosmatopoulos, E.B., Papageorgiou, M., Vakouli, A. and Kouvelas, A., 2007. Adaptive fine-tuning of nonlinear control systems with application to the urban traffic control strategy TUC, *IEEE Transactions on Control Systems Technology*, . 15 (6),. 991-1002.

Lambert, A. O., 2002. International report: water losses management and techniques. *Water Science and Technology: Water Supply*, 2(4), 1-20.

Pantazis, Y., 2019. An algorithm for identifying the location for placing acoustic leak sensors in municipal water networks. Working paper, Institute of Applied and Computational Mathematics, FORTH, Heraklion, Greece.

Puust, R., Z. Kapelan, D. A. Savic, and T. Koppel, 2010. A review of methods for leakage management in pipe networks. *Urban Water Journal.* 7 (1), 25-45.

Renzaglia, A., Doitsidis, L., Martinelli, A. and Kosmatopoulos, E., 2010. Cognitive-based adaptive control for cooperative multi-robot coverage. In: *2010 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 3314-3320.

Shamsi, U.M., 2005. *GIS applications for water, wastewater, and stormwater systems.* CRC Press.