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Session 6 - Environmental Systems: Management and Optimisation

Session 7 - New Methods and Technologies for Medicine and Biology

Session 8 - Embedded System Design and Application

Session 9 - Image Processing, Image Analysis and Computer Vision

Session 10 - Mobile Communications

Session 11 - Education in Computer Science and Automation

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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52nd Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
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N. B. Chang/ A. Gonzalez

A Decision Support System for Sensor Deployment in Water Distribution Systems for Improving the Infrastructure Safety

ABSTRACT

Meeting security objectives for a water utility is a challenging task. The need for thoughtful and comprehensive planning for prevention, mitigation, response and recovery from an event became even clearer after the attacks of 9/11. In response, an Emergency Response Plan (ERP) for water supply systems is now required under the Bioterrorism Act of 2002 in the US. As part of this process, each US utility will incorporate the results of their Vulnerability Assessment into an existing or new ERP. The goal of this paper is to introduce the architecture of an intelligent decision support system in this emerging area for decision support in emergency preparedness and response for water utilities. It presents the integration of knowledge acquisition, ontology modeling, expert system evaluation, and environmental assessment for structuring an environmental decision support system.

INTRODUCTION

There are nearly 60,000 community water supplies in the United States serving over 226 million people [1]. In an uncertain world, the prepared water utilities must provide safe and reliable water supplies in spite of natural and man-made disasters. In general, the framework for water utility protection comes in six parts, from environment to convey, to treatment, to storage, to distribution, and to point of use [2]. Natural disasters of concern may include earthquakes, floods, wind, public health, drought, hurricane, fire, and volcanoes. Human-caused disasters of concern may include electric power failures, communication and information failures, accidents and fire, hazardous material releases and contamination, security threats, equipment failure or line breaks. They are circumscribed by dotted lines alongside the service system to help identify the boundaries of the impacts that could be either conventional or non-conventional.

Meeting the security objectives for water utilities is an obviously challenging task. The need for thoughtful and comprehensive security planning for preventing an event, mitigating the impact of an unavoidable event, responding to an event, and recovering from an event became even clearer after the terrorist attacks of September 11, 2001 [3]. In response, an Emergency Response Plan (ERP) for water supply systems is now required under the Bioterrorism Act of 2002 in the United States. Each U.S. utility will need to incorporate the results of their Vulnerability Assessment into an existing or new ERP. The US Environmental protection Agency identifies three major steps in developing procedures - response, recovery, and remediation, with a list of initial and recovery notification required [4]. It should be consistent with the crisis management structure set out under the National Incident Management System enacted by the US Department of Homeland Security on March 1, 2004, which provides standardized protocols and procedures to coordinate the efforts of water systems and first responders during emergencies. Having a well-thought-out intelligent decision support system (DSS) in place before an extraordinary event strikes allows public officials to quickly respond to and stabilize chaotic situations.

The goal of this paper is to introduce the architecture of an intelligent DSS in this emerging area and delineate how to develop integrated ontological engineering analyses, expert systems' evaluation, and environmental modeling platforms for decision support in emergency preparedness and response for water utilities. It particularly presents the process of knowledge acquisition, ontology modeling, expert system evaluation, and environmental assessment for structuring the environmental decision support system (EDSS). This EDSS will help the users learn from experts with practical experience in developing the sensor network plans for Vulnerability Assessment (VA) and putting them into effect in all aspects. Based on the elements that go into this EDSS, it may help to determine a sound monitoring process to effectively implement ERP in a water utility.

METHODOLOGY

A key concept when determining or evaluating a potential threat to a water utility is the "design-basis threat," which is the credible threat that a utility's security systems are designed to protect against [5]. Identifying the design-basis threat should be based on knowledge of the threat profile in a specific area, as well as past events from which a good source of information on the region's threat profile. Prior to the 9/11 terrorist attacks, most water utilities would have identified an operational accident, such as chlorine gas leak, or natural disaster, such as storm events resulting in high turbidity source water, as the primary threat to their utility. Nowadays, the possibility of deliberate disruptive terrorist attacks must also be considered. Achieving this goal could call for an advanced planning, design, and operation of sensors and sensor network in response to the acute needs for building an EDSS.

In the past, advanced early warning systems around the world can be found in Ohio River (USA), Paris (France), St. Clair River (Canada), River Trent (United Kingdom), River Dee (United Kingdom), Yodo River (Japan), Rhine River (multiple countries), Edmonton (Canada), etc [6]. There are also numerous traditional exterior and interior detection sensor technologies available for various type of VA in these early warning systems. For example, monitoring stations installed in River Trent, United Kingdom, generate alarms based on water quality, and telemeters this data to treatment facilities for emergency response. In this case, the following are considered to be the most significant pollutant risks, including pesticides, ammonia, dissolved oxygen, chlorate, bromide, nitrate, boron, nickel, antimony, Giardia, Cryptosporidium, total phenols, polycyclic aromatic hydrocarbons, and hydrocarbons. In addition to traditional instruments, emerging monitoring techniques have been developing with unprecedented speed. Most notable in this development is the biosensors for testing the bacteria/viruses/protozoa, given that waterborne pathogens had been a long standing threat to human societies. A critical issue in water utility is how to utilize the knowledge about those newly-developed sensors to aid in the design of emergency preparedness and response systems in the near future, including the early warning systems. This paper aims to present a unique viewpoint from an Artificial intelligence (AI) perspective for promoting risk-based DSS in emergency events.

Monitoring Technologies

The accidental discharge of contaminants from various industrial sources and natural floods might occur at unpredictable times. In the past, online physical and chemical sensors were installed to detect physical and chemical parameters, such as temperature ammonia, turbidity, color, conductivity, pH, dissolved oxygen, conductivity, oxidation reduction potential (ORP), chloride, hardness, alkalinity, particle numbers, volatile organic compound (VOC) (e.g., such as Methyl, Tertiary

Butyl Ether, MTBE), toxicity (Microtox monitor), total organic carbon (TOC), some inorganic matter (UV Kontron), water quality (e.g., Hydrolab depth sampling), and flavor profile (e.g. methylisoborneol (MIB) and geosmin). Plant operators normally count on color and turbidity measurements for chemical dosing and control. For example, both powered activated carbon (PAC) and alum are added in response to high levels of color and turbidity. Yet, detection and identification of microorganisms on a real-time basis would significantly further reduce the risk of contaminated water reaching the end-users. In recent years, there are some bio-monitoring stations that had been deployed in river systems, such as the cases of river Rhine, Japan and South Korea, to supplement their extensive system of online gas chromatographs in source water. Several types of fish tests, daphnia tests, mussel tests, bacteria tests, and algae tests were applied in parallel with any online physical and chemical sensors. On a routine basis, analyses are performed for samples taken at different depths in the reservoirs, lakes, and rivers to detect Chlorophyll-a, plankton, zooplankton, etc. in response to public heal concerns.

In response to special needs, there are many emerging monitoring techniques that are on the horizon. Some of them have started becoming commercially available while the others are still in an exploratory phase. The new technologies, such as an electronic nose using acoustic wave sensor, quartz micro balance (QMB), metal oxide (MOX), and polymer composite sensor (PCS), are emerging. The last, has been used in California to detect algae blooms and odor problems. In addition, methods for real-time measurement of trihalomethanes (THMs) and haloacetic acids (HAAs) in water distribution networks are highly desirable because of the promulgation of Maximum Contaminant Levels (MCLs). Some emerging methods are becoming gradually available [7]. Yet, there is a growing concern of bioterrorism in water supply, such as the introduction of Cryptosporidium [8]. Some rapid bacteriological methods, such as DNA-gene chip technology, flow cytometry, immunoassays, polymerase chain reaction (PCR), electrochemiluminescene, ribotyping, bioluminescence, and immunomagnetic separation (IMS) have been devised to meet the real-time needs for online measurement [6]. The Oak Ridge National Lab has devised a new tool, AquaSentinel, to detect a broad spectrum of poisons. AquaSentinel will be commercialized soon [9]. These new and emerging monitoring techniques may aid in vulnerability assessment by providing an additional dimension of crucial information for decision making.

Environmental Decision Support System

The proposed rule-based expert system for the customized sensor network in a GIS platform will be derived from extensive experience in modeling water transmission and distribution networks. The primary concern is the disruption of supply to a large number of customers in rural communities with all the consequences for disrupting fire fighting capabilities and public health risks. The optimal locations for sensor deployment may then be drawn from multi-dimensional simulation outputs with respect to associated statistical indices. Contaminated water can have potentially catastrophic impacts on the health of end users, such as happened in Milwaukee, Wis., in April 1993 where a cryptosporidiosis outbreak infected more than 400,000 water consumers. In Gideon, Mo., in Nov., 1993, a Salmonella outbreak resulted in the death of seven individuals [12]. Integrating modeling and mapping systems to realize the contaminant kinetics and modeling strategies becomes the recent focus, promoting system reliability and the ability to present the risks to customers in a more amiable way [10, 11]. Specific uses generally require particular model synthesis and integration. For example, the assessment of THMs and HAAs in water distribution networks must rely on the combination of water quality models and hydraulics models (e.g., such as Hardy-Cross method). Vulnerability assessment can be further made possible by combining sensors with models to determine what would be the optimal locations in the water supply systems to deploy and which type of sensor is required for corresponding location. Models required in this area include hydraulic models, steady state water quality models, dynamic water quality models, optimization models, and display/visualization models. The models encompass a wide range of methods that can be used to predict the water quality in source water, treatment trains, and water distribution networks under a set of conditions. Ontology modeling can b integrated with environmental models for decision making. Some ontologies issues have been investigated for groundwater contamination and remediation in which dynamic semantics and task-oriented knowledge are often represented by rules or problem-solving methods [13, 14, 15]. The appropriate use of sensors/sensor networks in an EDSS would be able to combine all early warning information from source water monitoring systems to process monitoring of water treatment plants, and to the monitoring of water quality in distribution systems. On a design-basis, striving to link all critical components together, the advances of ontological engineering may further promote the functionality of the EDSS by providing a friendly design tool for the collection and selection of sensors and predictive models. Seamless integration of the EDSS into current SCADA systems can be anticipated by appropriate applications of water quality and demand forecasting, process modeling and assessment, inferential sensing, and process control [16].

CONCLUSION

Current regulatory pressures are driving the drinking water industry to more sophisticated levels due to the recent homeland security and public health concerns. An EDSS integrating AI and traditional DSS techniques can be developed for most drinking water treatment process, covering from source water, transmission system, treatment facilities, finished water storage, distribution system, and supporting infrastructure. It is also essential that the importance of online analyzers in the advanced real-time monitoring system be reflected in the development of an EDSS as well as the implementation of effective analyzer quality assurance and error detection programs.

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