Application of Spatiotemporal Informatics to Water Quality

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OBJECTIVE

In the District of Columbia, *combined sewer overflows* (CSOs) and *stormwater discharges* contribute significant pollution to the Anacostia and Potomac Rivers and Rock Creek. This project will devise and verify an innovative technology that can continuously monitor and measure the runoff quantity and quality in real-time.

MATERIALS AND METHOD

A real-time and continuous assessment of the severity of the runoff pollution in each sewer outfall (and the associated sub-catchment within the watershed) is necessary. However, the management difficulties and high costs of any conventional human-involved data collection approach may pose major challenges. In the application's backend, we see a timely and critical demand for an innovative and cost-efficient approach to continuous and real-time measurements of the runoff quantity and quality.

Our proposed approach is based on a newly developed Sun Small Programmable Object Technology (SPOT) computer (Figure 1). This tiny computer-sensor platform consists of stacked three layers [http://www.sunspotworld.com/docs/]: Li-Po Battery, Sensor Board, and Tiny Computer with a CPU (Java programmable), timer (AT91 timer for measuring time elapses), USB, power switch, and memory. The sensor board includes the following: 3-dimensional accelerometer (LIS3L02AQ), temperature sensor, light sensor, eight LEDs, two switches, five general-purpose I/O pins, and four high current output pins. Figure 1 shows SPOT devices in our laboratory. Currently, in our laboratory 6 SPOTs and three base stations are available for this project.

The proposed methods of this project are as follows:

Instrumentation: Encase a SPOT computer inside a sealed plastic sphere and tether it inside each target sewer outfall pipe as shown in Figure 2 (a lab-made small pipe and artificial water input will be tested before actual field tests; before the field tests).

Runoff logging: The 3D acceleration data stream (swing motions) from this sensor represents the runoff flow over time. The project will also try to see if some jerky motions caused by physical debris or sudden water bursts can be usable data; This project will conduct various lab experiments based on literature and case survey; In addition, the project will also try the temperature sensor of the SPOT to log temperature changes. More sensors can be connected to the SPOT.

Filtering and Aggregation: The programmable SPOT can filter-out insignificant events for optimal use of storage and communication bandwidth and can provide representative summary data (pre-processing) given a defined formula.

Students involved in the project will drive or walk by the sites with a laptop computer equipped with a SPOT base station on a regular basis (again, lap tests will proceeds this field test). All logged data will be automatically transmitted to the laptop's hard disk. Then, students will copy the collected data to a server computer located in our laboratory. After this project, in a larger project proposal, a modified SPOT with WAN/Cell network interface, which can transmit data directly to a remote server via internet, will be discussed.

The project team will consider installing a cellular phone charging solar panel (, which can be found in the market,) at each site and connect the charging mini USB cable to the SPOT. This will eliminate the need for manually opening the sphere to replace or charge the battery.

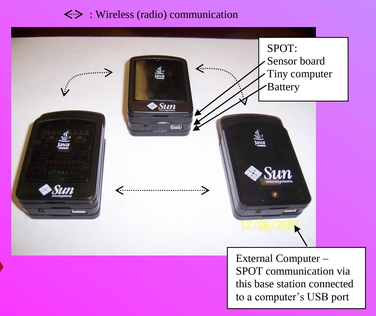

Figure 1. Our laboratory has four SPOTs and two SPOT base stations: The physical dimensions in mm are 71mm×42.40mm×18mm. The tiny computer can run any Java program that accesses the sensor board.

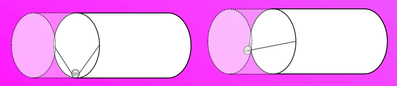

Figure 2. SPOT Sphere and its swing motion inside a sewer at an outfall

RESULTS

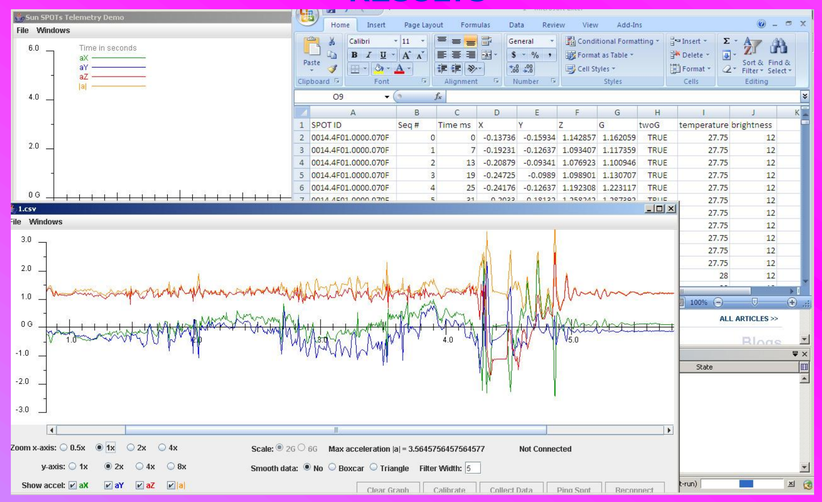

Figure 3. Developed SPOT software logging and plotting <time>, <3D accelerometer data>, <temperature>, and <light intensity> in a text file and on a chart. All programs are written in Java and loaded in the SPOT.

From Computer Science and Information Processing perspective, the main issue is the fact that any sensor data is associated with some past, current, and future missing (undetected) stimuli values. This is due to the fact that, although the input runoffs and pollutions can continuously change over time (they are natural phenomena), no sensor-computer can have infinite sensor resolution, update frequency, and computation power. Especially considering remote sensor platforms, additional data loss can occur because of various reasons including maintenance time, system upgrade, temporary power outage, and communication loss.

DISCUSSION

The impacts of the project include the following:

- By designing and validating a new extensible sensor platform, the proposed runoff monitoring system will effectively realize cost-efficient and continuous monitoring of the runoff quantity and quality;
- The new platform's computing power will enable programmed/customized pre-analysis of raw runoff data and trigger mechanisms that can attract human's attention (for emergency response or maintenance decision making support in real-time) when necessary (based on programmable/customizable rules);
- By exploiting wireless communication facilities and the programmable data processing power in the platform, the project will fill the existing gaps in the way information is gathered and disseminated among various stakeholders, when fully implemented;
- Upon completion, this proposed project will build a larger project proposal on developing an effective and efficient water quality monitoring system at the combined sewer outfalls and in the Anacostia, Potomac Rivers and Rock Creek.
- A significant cost can be reduced in the expansive water quality monitoring systems as this project will devise latest sensor technology combined with computer database systems.
- Importantly, this project will create an excellent opportunity for training under graduate and graduate students, researchers and water quality engineers and scientists in the area of water quality monitoring and decision making in both laboratory and field environments.

TAKE HOME MESSAGE

Urban storm-water pollution is a large contributor to water quality problems, as runoff transports a wide spectrum of pollutants to local receiving waters and as their cumulative magnitude is large [WEF, 1998].

The pollutants in urban runoff include visible matter, suspended solids, oxygen demanding materials, nutrients, pathogenic microorganisms and toxicants such as heavy metals, pesticides and hydrocarbons. These pollutants affect aquatic life and human health [Field et al., 1998] and impair the designated uses of water resources.

Typical urban stormwater-runoff-related receiving water quality problems include the degradation of aquatic habitats, degradation in water quality during and after wet weather events (e.g., rainfall and snowmelt), beach closures, and accelerated rates of eutrophication in lakes and estuaries, and thermal pollution [WEF, 1998].

These problems have been prevalent in most receiving water systems in the vicinity of urban or urbanizing areas.

LITERATURE CITED

WEF Manual of Practice No.23, Urban Runoff Quality Management, ASCE, Alexandria, VA, 1998.

Field R., M. Borst, T. P. O'Connor, M. K. Stinson, C. Fan, J. M. Perdek, and D. Sullivan, Urban wet-weather flow management: research directions, *J. Water Resour. Planning and Management, 124(3)*, 168-180, 1998.

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