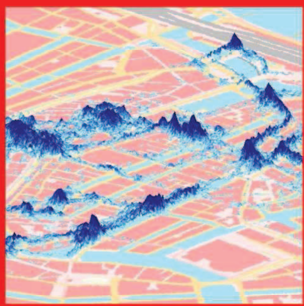
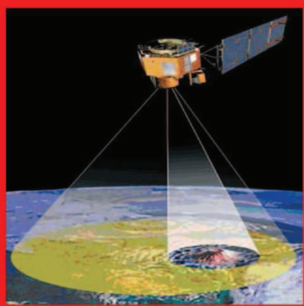
Sensing a Changing World

Proceedings workshop Nov. 19-21 2008





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Arend Ligtenberg

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Geo Mindstorms: Investigating a sensor information framework for disaster management processes

Steven Fruijtier [1,]*, Eduardo Dias [1,2] and Henk Scholten [1,2]

1 Geodan S&R, President Kennedylaan 1, 1079 MB, Amsterdam, The Netherlands
2 SPIN*lab,* Vrije Universiteit, De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands

E-Mails: steven.fruijtier@geodan.nl; eduardo.dias@geodan.nl; hscholten@feweb.vu.nl

* Author to whom correspondence should be addressed; Tel.: +31-20-5711311; Fax: +31-20-5711333

Abstract: The increasing availability of sensor information can generate added value and facilitate decision making when integrated in disaster management processes. In this paper we investigate and demonstrate the use of sensor data in two different setups, a laboratory and a field case. The first setup is a laboratory environment using a Lego Mindstorms NXT robot and sensors where technical challenges the integration of sensor data can be explored. The second setup is a serious gaming environment where the use of different sensor information is evaluated by disaster management operators in order to define its added value for the decision process. Preliminary results show that the Lego Mindstorms NXT offers an effective and more efficient framework to research and demonstrate several aspects of sensors, aspects which can then be tested in virtual scenarios.

Keywords: Lego Mindstorms, disaster management, sensor web enablement

1. Introduction

The recent availability and advances of real-time sensor information are of rising importance in areas such as Disaster Management [1,2]. For example, during a flood situation multiple sensor types can supply crucial real-time information for decision making by the disaster managers. Sensors can inform on water levels and dike strengths to allow the prediction of developments. Cameras can monitor the traffic on the highways or other sensors can measure the flow of traffic allowing for the informed definition of evacuation routes. Concentrations of toxic gasses measured by mobile teams together with real-time weather information are used to calculate gas clouds exposures. If no sensors were previously deployed in the area, mobile sensors can be used to report about the situation in real time. Examples of mobile sensors are wearable systems like the I-Garment [3], where sensors are embedded in the clothes of disaster fighters to report on their location, health and surrounding environmental conditions or sensors carried by Unmanned Airborne Vehicles (UAV). UAVs can be used to provide sensor information at affected sites which are in principle inaccessible to first responders [4,5]. Sensor measurements include the location and time allowing for location-aware services based on the measurements.

Real time sensor data can be useful on its own, but it can deliver even more added value when it is combined with spatial information of the area (such as demographic socio-economic or topographical data). Therefore, the incorporation of (processed) sensor data in a spatial data infrastructure (SDI) is of rising importance in areas such as disaster management and for early warning systems. For example, the mentioned gas cloud derived from sensor data is more valuable when it can be used in combination with population data to determine the number of people affected and to decide which area has to be evacuated [6]. Also, background road networks can be used to calculate safe routes for first responders depending on their location and status.

In the framework of the GDI4DM project [7], a Dutch Government funded project, we are studying and developing an infrastructure to support decision-making and information exchange during the disaster management phase. This infrastructure for disaster management will be tested and evaluated, with respect to sensor information, using two different approaches:

1. A laboratory environment where sensors are used and their data simulates potential real situations.
2. Serious gaming exercises: to evaluate the gathered experiences in practice.

In this paper we focus on the laboratory environment where we used an accessible framework based on the Lego Mindstorms NXT system. The serious gaming environment is planned to be carried out by disaster management organisations in the Netherlands in November 2008 and will show how sensor data can have a positive impact in the disaster management processes.

The following section elaborates on the framework that implements sensors data in an SDI. The relevant standards are introduced and the architecture is described.

2. Architecture and standards

The GDI4DM infrastructure [8] is based on Open Standards, such as OpenGIS (e.g. GML, WFS, WMS and CSW) and OASIS standards (e.g. BPEL). In order to integrate the sensor information in a SDI it is important to use standards allowing for interoperability. The Open Geospatial Consortium (OGC) initiative Sensor Web Enablement (SWE) [9] defines standards for e.g. discovering, managing and monitoring sensors. The SWE standards have been tested in the last OGC Web Services (OWS) initiative in the area of disaster management [10,11]. These testbeds are organized to demonstrate the interoperability of OGC standards.

The SWE defines several standards for discovering managing and retrieving sensor information of which the following will be used first:

- Observation and measurement (O&M) to encode the sensor data;
- Sensor Model Language (SensorML) to describe the sensor systems;
- Sensor Observation Service (SOS) to request, filter and retrieve sensor data.

Other specifications, such as planning and alert services can be added later depending on the evaluation of the disaster management exercises. The goal of Sensor Observation Service (SOS) [12] is to provide access to observations from sensors in a standard way that is consistent for all sensor systems including fixed and mobile sensors. It is therefore a critical element of the SWE architecture. Figure 1 shows the SOS concept.

Figure 2 shows some of the sensors which can be used during a disaster management process and how the sensor network fits in the general disaster management infrastructure. Some of the sensors have a fixed location and are often connected to a wired network, while others are mobile and communicate using wireless and even ad-hoc networks. The raw sensor data and/or the processed sensor information will be part of the Common Operational Picture which is essential for the situational awareness and effective decision support during a disaster.

Figure 1. Sensor Observation Service concept

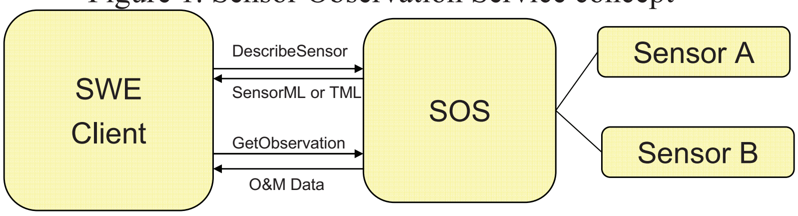
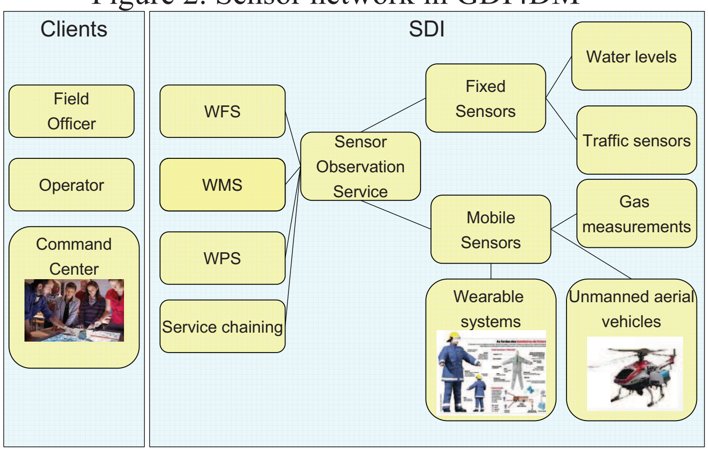


Figure 2. Sensor network in GDI4DM



3. Lego Mindstorms

The development of integrated systems for disaster management that use sensor data and its processed information comprises an additional challenge to the developers and system integrators. Often the sensors are not yet deployed and there is no access to the sensors data or processed information. This limitation makes it difficult to test the work processes in the system and developers then recur to the creation of their own test environments with sensors or simulated sensors to test the different parts of the processes. We explored the use of the Lego Mindstorms Robotic framework as a laboratory network of mobile and fixed sensors. The Lego Mindstorms is a programmable robot that supports different sensors and offers the possibility to examine, implement and demonstrate the usage of these sensor data in an affordable and inspiring way. Robotics is a flexible and powerful channel to demonstrate a variety of concepts [13]. Lego Mindstorms has already been extensively used in e.g. high schools, AI courses and used to test and demonstrate a wide variety of tools and techniques [e.g. 14,15,16]. This section describes the advantages of using this framework in the disaster management process.

As described above, sensors can be used in a multitude of ways in the case of Disaster Management. Therefore there are advantages in using a flexible tool, like the Lego Mindstorms, where different sensors can be easily deployed. Among others, benefits of using Lego Mindstorms include low costs, heterogeneous collection of sensor types (light, temperature, RFID, etc). Furthermore, this framework also enables flexibility in software development since it is already supported by many development platforms (e.g. Microsoft Robotic Studio) and open source initiatives [13].

Figure 3. Lego Mindstorms NXT based architecture

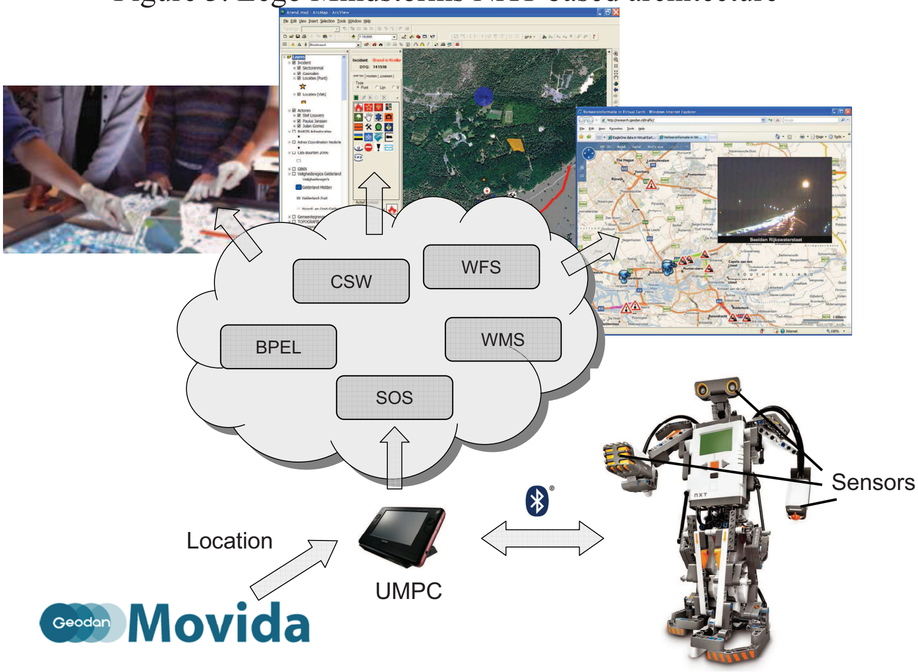


Figure 3 shows the architecture from figure 1 as it is used with Lego Mindstorms.

The Lego Mindstorms supports different sensors, like light sensor, measuring light intensities, and a sound sensor. You can also buy additional sensors like temperature, RFID and many more sensors. The sensors can be used for the different components of the OGC SWE, like the mentioned O&M, SensorML and SOS specifications and to test the integration into work processes and the spatial data infrastructure.

Determining the location of a robot by using the environment is not an easy task. In order to obtain the location of the robot the real-time location system Movida [17] is used. Movida is capable of locating the robot both indoor and outdoor using different techniques such as GPS, Wi-Fi, RFID or Ultrawideband. Based on its location the robot can take predefined actions (e.g. navigate; react on Poi's, etc). Also other systems (e.g. robots, software) could react to the location of the robot.

Recent developments indicate that first responders in the future will wear wearable systems containing sensors. E.g. suits like the I-Garment [3] measure the health status of first responders and send this information to field officers and control centers. This information flow and the subsequent reaction by systems and people can be implemented using the SWE Alert Service.

A different implementation of mobile sensors is its use in autonomous vehicles like UAV. Such equipment is often expensive and therefore inaccessible to small scale investigations. With Lego Mindstorms an inexpensive prototype can be easily build. The robot was also equipped with an Ultra Mobile PC (UMPC) communicating with Wi-Fi and therefore it is capable of receiving commands from external systems, simulating in this way a command & control situation.

4. Serious gaming

The SDI as described above, tested with the Lego Mindstorms, will be evaluated in serious gaming environments. Several scenarios have been defined and will be carried out by disaster management organisations in the Netherlands. For example in November 2008 a scenario based on a flooding situation will be simulated. A large amount of (geographical) information is used in the exercise, some of which are sensor information. The information is integrated and visualised in a dedicated Virtual Earth infrastructure hosted on behalf of the disaster management organisations.

5. Conclusions

The Lego Mindstorms is a very affordable tool to investigate different geo related subjects in an extremely easy (and motivating) way. Lego Mindstorms offers an effective way to research and demonstrate several aspects of sensors, like the Sensor Web Enablement standards, integration into the workflow, mobile and fixed sensors and even autonomous vehicles based on command & control and sensor information. In addition, it also makes it possible to demonstrate in a lively way the concepts of the OGC Sensor Enabled Web and Location based services to the stakeholders.

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