Sensor Web Architecture for Crisis Management

Nataša Marković[1], Leonid Stoimenov[2]

Abstract – **This paper presents architecture of a system for crisis management, based on the sensor web technology and Geo-Information Systems (GIS). Rapid development of new technologies, especially Sensor Web, brings many ways for environmental protection and maintenance. Combining GIS, as a platform for data visualization, with Sensor Web, enables us to create crisis management systems for environmental monitoring and protection.**

Keywords – **Sensor Web, Crisis Management, GIS**

I. Introduction

Geo-Information Systems (GIS) are being widely used for more than forty years. They have found their purpose in environmental monitoring, transportation management, public safety, facility security, disaster management, etc. GIS enables us capturing, storing, analyzing, and displaying geographically referenced information. It allows us to view, understand, query, interpret, and visualize data in a way that is quickly understood and easily shared. GIS technology can be used for scientific research, resource management, and development planning.

Sensor Web, on the other hand is a relatively new technology with wide usability. It enables tracking sensors, obtaining their data and making it available through the Web. According to [1], Sensor Web is a special type of Web-centric information infrastructure for collecting, modeling, storing, retrieving, sharing, manipulating, analyzing, and visualizing information about sensors and sensor observations of phenomena.

The point where these two separate technologies meet is a system where GIS provides maps and objects, and Sensor Web provides interface to sensor data. A general overview of one such system, where geo-location of sensors is interpreted on map, where sensors can be queried and their data represented, is further described in this paper.

The rest of the paper is organized in the following way: Section 2 describes existing technology standards, specifications and practical examples of GIS and Sensor Web systems. Section 3 describes the architecture of GIS and Sensor Web based Crisis Management system (GinisSenseCM). Activity flow and the activity diagram of the GinisSenseCM system is described with details in Section 4. At the end, conclusion and the review of literature is given.

[1]Nataša Marković is with the Faculty of Electronic Engineering at University of Nis, 14 A. Medvedeva, Nis 18000, Serbia, E-mail: natasa.markovic@elfak.ni.ac.yu

[2]Leonid Stoimenov is with the Faculty of Electronic Engineering at University of Nis, 14 A. Medvedeva, Nis 18000, Serbia, E-mail: leni@elfak.ni.ac.yu

II. Related Work

A. Standards and Specifications

In order to use, share and present data received from sensors we need to use a standardized set of protocols and semantics.

The Open Geospatial Consortium (OGC), as a leading organization in the development of standards for geospatial and location based services, has introduced a set of standards called Sensor Web Enablement (SWE). SWE consists of three Markup Language specifications including SensorML [2], Observation and Measurement (O&M) [3], Transducer Markup Language (TML) [4], and four Web Services specifications based on the assumption that all sensors are connected to the web, including Sensor Planning Service [5], Sensor Observation Service [6], Sensor Alert Service [7] and Web Notification Service [8]. This set of services and specifications contributes to exploiting Web-connected sensors and sensor systems of all types: flood gauges, air pollution monitors, stress gauges on bridges, mobile heart monitors, Webcams, satellite-borne earth imaging devices and countless other sensors and sensor systems. OGC specifications also include protocols for data access, such as Web Map Services (WMS), Web Feature Services (WFS), and Web Coverage Services.

B. Practical Examples

Technologies, specifications and protocols mentioned above allow us to create various crisis management applications (disaster management applications, environmental protection and management applications, etc). We will describe in this section two environmental monitoring applications.

An application for detection and monitoring the spread of wild fires [9] uses Sensor Web technology for wild fire detection in Africa. Their aim is to use the Sensor Web to observe specific fire-related phenomena described in the wild fire ontology and employ machine reasoning to determine fire risk. In that way it is possible to predict the occurrence and spreading of wild fire, in order to inform the responsible services so that they can act accordingly and prevent possible disaster.

The South East Alaska MOnitoring Network for Science, Telecommunications, Education and Research (SEAMONSTER) [10] is a smart sensor web project designed to support collaborative environmental science with near-real-time recovery of environmental data. Their work is focused on the Lemon Creek watershed and understanding both physical and biological as a collection of interconnected systems. This project is an effort to implement a sensor web available for science, education, and sensor web technology evaluation and advancement.

These and many other applications relay on different, specialized architectures. What we have created is a general architecture for crisis management, which could be easily adopted for concrete purposes.

III. GINISSENSECM ARCHITECTURE

The general architecture of the GIS and Sensor Web Crisis Management system (GINISSENSECM) is given in Fig. 1. It consists of the following components: System Operator located at the Crisis Management Center (CMC), Graphical user interface (GUI), Databases, the Decision Making Agent (DMA) and Data Access Layer.

Graphical User Interface is a WebGIS [11]. The user interacts with the GUI, which visualizes data received from different data sources (sensors or community services) as well as objects of interest.

Crisis Management Center (CMC) is a center for resolving numerous problems related to environmental protection. CMC activities are gathered around making decisions on the basis of gathered information about the environment and acting in order to prevent disasters or threats related to the observing environment.

Decision Making Agent (DMA) is a component used for comparing and analyzing data obtained from different sources, making action plans, executing automated spatial queries, running on demand or automated actions and proposing action plans to CMC operator. The DMA component is responsible for executing automated spatial queries, data acquisition from sensors and Community services, and decisioning and acting based on the set of operator demands, or programming logics. DMA component is still in the development phase. So far it is planed as a component consisting of the following subcomponents: knowledge database (support for rules), decision component, interface to user/other component, interface to data sources.

DMA Agent can be configured to act according to operator commands. For now, DMA can act upon two types of events: **on user input** and **on measured values**. From the configuration interface dialog, operator chooses type of event, after which new dialog appears depending on chosen event. In the user input event dialog, operator chooses few keywords from a defined set of metadata, for example ***dump+river***. After choosing the set of keywords, user then configures DMA actions upon the following event: when user input has as metadata keywords **dump+river**, do the following. An action configuration dialog has for now following possible actions: Inform operator on event by **sms/mail**, Alert registered users upon event and Repeat Measurements (for actions based on measured values). So after final step in the DMA configuration the sentence describing acting upon event would be: *When user input has as metadata keywords dump+river inform operator by sms.*

We gave here the example of DMA configuration, upon acting on user input. Different dialog would be for acting upon measured values. In the measured values event dialog, operator configures which values to be monitored and in what range. After choosing range and values of measured parameters, DMA actions dialog appears, same as in the previous paragraph. After final step in the DMA configuration the sentence describing acting upon measured values would be: *When measured values of ph+T is exactly 6,3+34,8 repeat measurements AND alert registered users.*

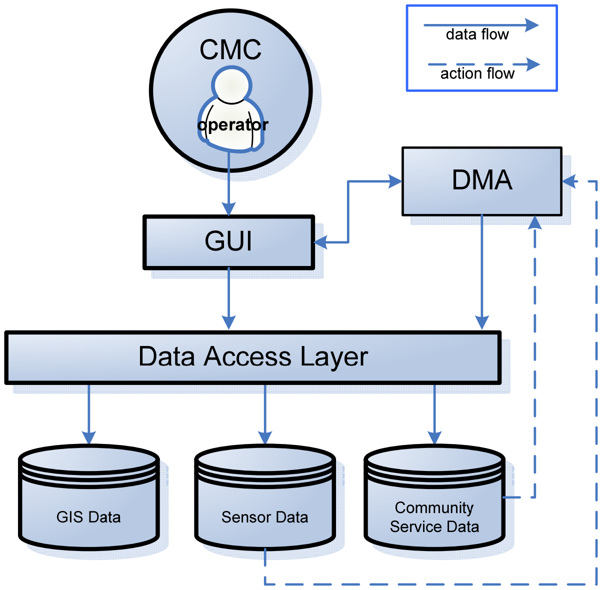

Fig. 1. GINISSENSECM Architecture

Data Access Layer (DAL) represent implementation of different services which enable access to different data sources and are responsible for information flow in the system. DAL is the intermediary between an operator and a data collection management environment.

Databases store data received from sensors, as well as data received from community services and GIS data.

IV. GINISSENSECM ACTIVITY FLOW

The activity flow of the GINISSENSECM system is shown in Fig. 2. The central component of the activity flow is the Decision Making Agent (DMA). The DMA component, implemented using Web services technology, has two major roles. First role is to process automatic measurements based on operator demands. The second role is to decide if there has been major changes in measuring parameters, and offer some actions to the operator or act accordingly (if operator allowed this during DMA configuration). Instead of using only values received from different types of sensors in the process of deciding whether there is a possible threat in the observing environment, CMC operators are provided also with data received from community services. Gathered data is compared and analyzed by DMA and on that basis conclusions are presented to the operator with greater reliability. Activity flow also includes three Web services: Sensor Observation Service, Web Notification Service and Sensor Alert Service, which are responsible for collecting data from sensors, managing sensor actions in real time and delivering notifications to end users.

These services are implemented on the basis of OGC SWE specifications.

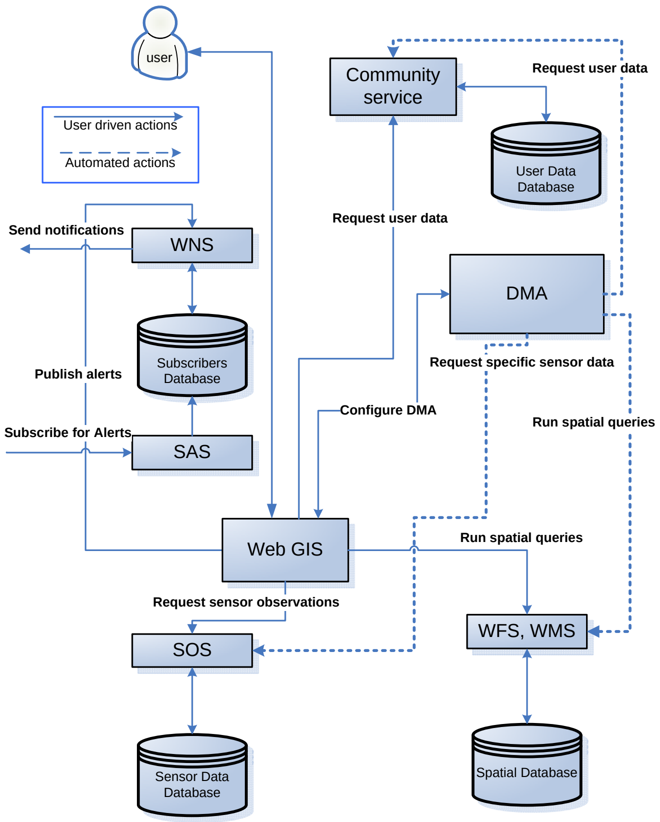

Fig. 2. GINISSENSECM Activity flow

The Community service is a Web service for collecting data from users concerning the environment. It allows users to send information in various ways about their observations of the environment. For example, a certain user could send a picture of dump, fire, etc, which would be useful when decision is made about the various sources and causes of pollution, fire or any other environmental threat or disaster. Community services should register within system in order to be able to interact with the system and send collected user data in various formats (e.g. pictures with descriptions, textual messages …).

GIS data represents a collection of geographical data, maps, vector and raster objects. This component represents different data depending on the system purpose. For example if the final implementation of the system is used for water management, GIS needs to incorporate data about rivers. GIS data is stored in spatial database over which can be executed operator driven or DMA automated spatial queries. There is a predefined set of spatial queries among which the operator can choose one to execute, which is the most appropriate for the current situation.

Operator can choose a type of query executed by DMA agent that will be triggered by some event on the sensor. An example query would be to request objects to be drawn on the map if they are classified objects of threat for the environment) (as illustrated in Fig. 3.a).

a) **SELECT** {objects} FROM {SpatialData D} **WHERE** {object.property **IN** {polluters}}

b) **SELECT** {parameter} **FROM** {SensorData D1, SensorData D2} **WHERE** {D1.loc IN (R1) **AND** D2.loc **IN** (R2)}

c) **SELECT** {metadata} **FROM** {UserDatabase U} **WHERE** {U.loc IN (R1)}

Fig. 3. Example data queries

Sensor Database stores the data obtained through Sensor Observation Service (SOS). SOS is a standard Web service interface for requesting, filtering, and retrieving observations and sensor system information. Operator driven or DMA automated queries are executed over sensor database. For example, user can request the measuring parameters received from the sensors located in two different regions (as illustrated in Fig. 3.b).

User Data Database stores user collected data concerning environmental protection. For example someone can send a picture of environment (waste water, wild dump, object in fire, etc), with a small description of what is in the picture and its geo location. User data can be filtered and queried in different ways. One possible query could be for finding the metadata (user description) for some location (as illustrated in Fig. 3.c).

The activity diagram (shown in Fig. 4) shows basic activities performed in the system by user or configured DMA component. There are two types of actions that can be performed in the system, user driven actions and automated actions.

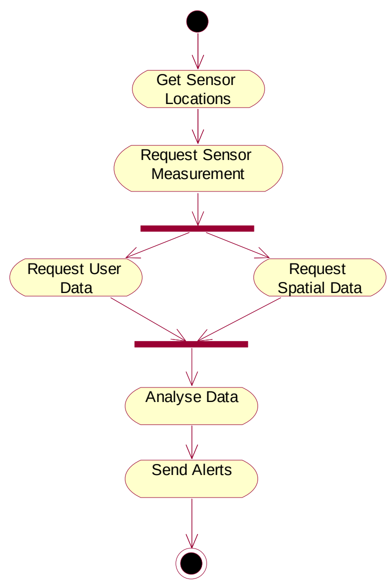

Fig. 4. GINISSENSECM activity diagram

A. User driven actions

User driven actions are associated either with sensors, GIS data and community services or with the DMA component.

The user (operator – further in the text) located at the CMC *Request Sensor Measurements*, in order to check measuring parameters. At the same time, he can also perform two more activities *Request User Data* and *Request Spatial Data*, in order to have a more detailed view on the observing environment. On the basis of received data, operator can analyze data and decide about the actions to be performed. If a possible threat is detected, operator can *Publish Alerts* in order to inform objects of interest. If the operator gets some conclusions about who is responsible for the threat, he can inform them as well. Operator can ask for sensor observations through Sensor Observation Service. He can send request to WMS and WFS services if he needs to see where the sensors are geographically situated. Operator can check the community service data, and finally, when it is needed he can publish alerts and notifications using Web Notification Service.

B. Automated actions

The second types of actions that are possible in the CM system are automated actions. Automated actions are performed by DMA on the basis of operator configuration. Operator configures DMA in order to define a set of rules and actions to be performed automatically in some period of time. For example operator can fill a simple form to initiate specific measurements to SOS, which will be saved into database. DMA can run on-demand sensor observations continuously in certain period in time, and cross-reference the given values with data obtained from community service database. On the basis of predefined criteria, DMA can decide whether the vital parameters are beneath or above certain level, and propose actions to the operator.

V. CONCLUSION

Sensor Web has provided infrastructure for collecting and processing data from distributed and heterogeneous sensors. This set of technologies has found various implementations, especially in the area of environmental monitoring. The GIS and Sensor Web architecture for Crisis Management (GINISSENSECM), described in this paper, provides active monitoring of measured parameters and timely responses in cases of environmental disasters. The Crisis Management System based on Sensor Web and GIS enables access, control and management of desired environment. The GINISSENSECM system is general and it can be personalized and used for concrete purpose. For example if the sensors are situated in river water, the GINISSENSECM system can be used for tracking and managing water pollution, publishing alerts and prevention of the possible disasters (in the cases of releasing toxic substances in water) [12]. Another example of implemened GINISSENSECM architecture is the GinisED DistSense system [13] for tracking parameters of power supply network in real time. The GINISSENSECM system can also be used for fire prevention in buildings as well as for open spaces. The GINISSENSECM system is easily adjustable for management and prevention of any other environmental disaster or threat. There are many ways of upgrading this system and making it more efficient and completely automated. The future work includes modifications and improvements of the current system architecture and its implementation. The DMA component can be further improved by incorporating a knowledge-based engine, in order to run independently and automatically report alerts to the operator in the crisis management center.

ACKNOWLEDGEMENT

Research presented in this paper were partially funded by the Ministry of Science of the Republic of Serbia and PD Jugoistok Niš, within the project in the field of technological development "Intelligent integration of geo-, business and technical information on the company level," No. 13003.

REFERENCES

[1] N. Gross, *Business Week,* Aug. 1999, www.businessweek.com/1999/99_35/b3644024.htm
[2] M. Botts, (Ed.), OpenGIS® Sensor Model Language Implementation Specification (Version 1.0). OGC Document Number: 05-086r2, 117pp., 2006.
[3] S. Cox, (Ed.), OGC™ Observation and Measurement (Version 0.13.0). OGC Document Number: 05-087r3, 136pp., 2006
[4] S. Havens, (Ed.), OpenGIS® Transducer Markup Language Implementation Specification (Version 1.0. 0). OGC Document Number: 06-010r2, 136pp., 2006
[5] I. Simonis, (Ed.), OpenGIS® Sensor Planning Service Implementation Specification (Version 0.0.30). OGC Document Number: 05-089r1, 152pp., 2005
[6] A. Na, M. Priest, (Eds.), OpenGIS® Sensor Observation Service Implementation Specification (Version 0.1.5). OGC Document Number: 06-009r1, 187pp., 2006
[7] I.Simonis, J. Echterhoff, (Eds.), OGC® Sensor Alert Service Implementation Specification (version 0.9.0). OGC Document Number: 06-028r5,144pp., 2006
[8] I. Simonis, A. Wytzisk, (Eds.), Web Notification Service (Version 0.1.0). OGC Document Number: 03-008r2, 46pp., 2003
[9] A. Terhorst, D. Moodley, I. Simonis, G. McFerren, F. Van den Bergh, "Using the Sensor Web to Detect and Monitor the Spread of Vegetation Fires", In: Advances in Geosensor Networks, Springer Lecture Notes in Computer Science Series, 2008.
[10] MJ Heavner, DR. Fatland, E. Hood, C. Connor, "SEAMONSTER: A Sensor Web Technology Implementation and Testbed in Southeast Alaska," presented at NASA Science and Technology Conference, College Park, MD, June 19, 2007.
[11] M. Bogdanovic, N. Davidovic, I. Antolovic, A. Stanimirovic, D. Stojanovic and L. Stoimenov, "WebGIS application for viewing and analysis of electric power supply network geodata", YUINFO 2008, Kopaonik, (in Serbian)
[12] N. Markovic, A. Stanimirovic and l. Stoimenov, "Sensor Web for River Water Pollution Monitoring and Alert System", AGILE 2009, (accepted for publishing)
[13] M. Bogdanovic, N. Markovic, A.Stanimirovic and L. Stoimenov, "GinisEd DistSense – Sensor Web inside GinisED system", Etran 2008, Palic, (in Serbian)