# Multi Agent Architecture for Environmental Data Collection and Validation


**Ljiljana Bodrožić, Darko Stipaničev, Mario Šerić**

**Department for Modeling and Intelligent Systems**
**Faculty of Electrical Engineering, Mechanical Engineering and Naval Architecture**
**University of Split, R.Boskovica bb, 21000 Split, Croatia**
**Phone: (385) 21 305 813 Fax: (385) 21 463 877 E mail: ljiljana.bodrozic@fesb.hr**



***Abstract: As a result of rapid advances in technology development, we are witnessing numerous environmental changes, with serious consequences like pollution, meteorological anomalies, land desertification and similar. Environmental Information Systems (EIS) and Environmental Monitoring Information System (EMIS) are intensive research areas, partially due to the efforts on more efficient environmental protection and partially due to the IC (Information-Communication) technology development providing new environmental protection methodologies and treatments. A sensory network based on automatic ground monitoring stations enables more flexible real-time environment monitoring and protection. This paper describes a part of our iForestFire system and explains in more details multi agent architecture of subsystem for collection and validation of environmental data important for high level processing and analyzing tasks. Theoretical background and experiences from 2005 and 2006 field experiments are given.***


## 1. Introduction

In latest century advances several technology areas has led to development of Wireless sensor networks, one of the most important technologies of 21 century. The three key technologies, responsible for development of wireless sensor networks are:

- Sensor technology, which resulted with low cost, small in size sensors and actuators
- wireless communication technology,
- and creating new algorithms for ad hoc topologies [1]

Sensor network consists of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions [2]. WSN can significantly improve the accuracy and density of scientific measurements of physical phenomenon because we can deploy a large numbers directly where experiments are taking place [3] .

When we are monitoring the environmental changes, we need to have real-time data readings from the sensors, as well as archive data trends and movements. That is why many sensor manufactures are offering Data Logging devices together with their sensors (National Instruments, Monitor Sensors, YSI, DeltaTrak and so on) with the task of collecting and logging the sensor data and displaying it when they receive a request, either via Internet or via RS-232 port [4,5,6,7]. Internet-enabled Data Loggers are preferred, mainly because of data accessibility.

Because of specific special distribution and large volume of data, modern programming technologies must be applied in sensor data acquiring and logging systems.

There are several ongoing projects dealing with this problem.

At UCSD (University of California at San Diego), real-time data grid called the Virtual Object Ring Buffer (VORB) was developed. The VORB is a multi-tiered architecture for accessing real-time data from distributed sensor networks [8]. Also, the InfoSleuth project – which took place at MCC (Microelectronics and Computer Technology Corporation) and with a goal of creating a unified system for data retrieval and processing – used agents for querying distributed environmental data-clusters in a transparent way [9]. At Lawrence Berkeley National Laboratory, Java Agents for Monitoring and Management (JAMM) agent-based system was implemented to automate the execution of monitoring sensors and the collection of event data [11].

In some applications, such as Multi Sensor Data Fusion project, by US Separtment of Defense, sensors are clustered together, making one platform [14]. We adopt the basic idea by defining a sensor node. **Sensor node** is a group of sensors and actuators clustered together, measuring the same scene from the same perspective. It can be characterized by one master node and numerous sensors it conrols, or just common geographic location.

As a part of European eyes project, three layer sensor network architecture is proposed, consisting of Sensors and networking layer, distributed services layer and application layer [15]. In our work, we implement the idea by defining multi agent system on each layer, and thus creating multi agent architecture above sensor network.

In our wok we don’t focus this much on physical aspect of sensor network, nor the wireless communication or ad hoc topography algorithms. Our interest is mainly on data the sensor network can provide us, and how can we use the data in our applications more efficiently, for information, and knowledge building.
In this paper, first we will describe the hierarchical architecture of sensor network, and parts of which each sensor node consists of, and how or sensor node fits into our iForestFire system. After that we will present unified architecture for sensor network data collecting and transformation to a form required by application. In addition, some basic outlines of verification system, based on commonsense reasoning [16] are presented.

## 2. iForestFire and sensor network

Our particular interest focuses on forest fire protection, as an important part of overall environment protection. Forest fire is a phenomenon with severe impact on vegetation, animals, landscape, soil, air and the human community living in those areas. The forest fire monitoring system is responsible for protecting large areas of land from devastation caused by forest fire by

a) real-time predicting forest fire danger index,
b) early spotting and detecting forest fire in initial phase and alarming responsible fire fighting units,
c) predicting forest fire development to support fire fighting management activities and
d) enabling distant video and meteorological presence at forest fire field also to support fire fighting management.

**iForestFire** is an Integral Forest Fire Monitoring System, and it provides these functionalities via web interface [17,18,19,20].

A typical user interface of the system can be seen in figure 1.

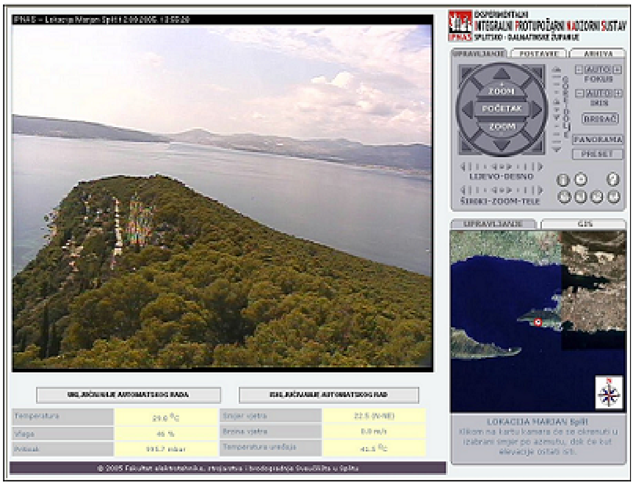

Figure 1: Typical user interface (location: Marjan, Split)

In our approach, which is now in development for the Split-Dalmatia County and is called the Integral Forest Fires Monitoring System [17], the system is a TCP/IP-based system conceived of:

- sensor network and
- central server units for collecting, processing and storing all data.

Each sensor node consists of:
- pan/tilt/zoom-controlled video camera connected to the network-embedded video Web server,
- mini meteorological stations connected to network-embedded data web servers, and
- wireless (IEEE 802.11 b/g) communication unit.

The system overview is shown in Figure 2.

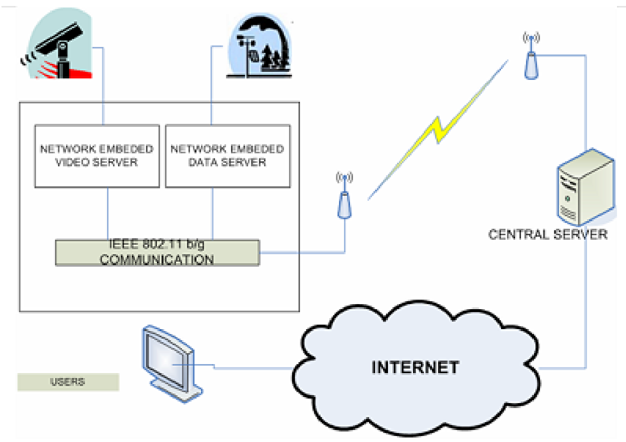


Figure 2: The concept of Split-Dalmatia County Integral Forest Fire Monitoring System

Sensor network is a physical part of the system deployed and integrated in the environment, covering the area of interest.

Our sensor network consists of simple, advanced and virtual sensors. An example of simple sensor is temperature sensor whose output is a number presenting a temperature level in degrees of Celsius. An example of advanced sensor is a vide camera whose output is digital image. And finally an example of virtual senor is a dew point senor, because there is no physical sensor for measuring this attribute, but the value is calculated using temperature and humidity sensor readings.

The relation of simple and virtual sensors to physical sensors is presented in figure 3:

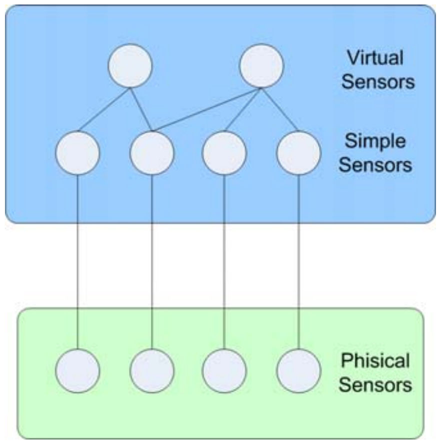


Figure 3: relation of simple and virtual sensors to physical sensor

Although our tendency was to create a system that would not depend on hardware and software platform, we had to choose a test platform for our experimental system.
In variety of sensors available on the market, low cost iButton 1-wire sensors were chosen for meteorological data sensing. Together with the TINI embedded microcontroller [23], this network embedded meteorological station forms a reliable measurement unit.

Reasons for choosing TINI were its simplicity, low power consumption, open-source software support and particularly Java interface, because our multi-agent based system was developed using JADE (Java Agent Development Framework) [24] as a development framework.

To unify the approach, a video camera connected to the video Web server was considered to be a video sensor, the same way as a temperature measuring element connected to the data Web server was considered to be a temperature sensor. To cover the whole surrounding space each camera had 8 preset positions, and each preset position was considered to be its own video sensor responsible for monitoring certain part of the landscape. This means that each camera was treated as 8 independent fixed cameras mounted on the same place.

A sensor node situated on the top roof of the faculty building, used in iForestFire system as one sensor node, can be seen in figure 4


Figure 4: Experimental sensory (monitoring) unit

### 3. Multi agent system for data collecting

Application of agent-oriented methodologies in process monitoring and control is a relatively new approach, particularly suitable for distributed and dislocated systems [10,12,13].

Formally, an agent could be defined as [21,22]: *"… an encapsulated computer system, situated in some environment, and capable of flexible autonomous action in that environment in order to meet its design objectives …"*

Agents designed for the forest fire monitoring system followed these guidelines strictly, because the system was conceived as a modular system where each module is **autonomous**, **aware of its environment** and **capable for active behavior** if alarmed.

Environment awareness is accomplished by connecting numerous meteorological sensors to a network-embedded microcontroller unit. Network-embedded microcontroller unit was responsible for collecting data from sensors, formatting and preprocessing it and giving it to the central server agent when asked for.

The network-embedded microcontroller unit is Ethernet-enabled and runs a simple web server application so that agent communication is implemented by HTTP connections. First data preprocessing (digitalization) was done by the sensor itself. After that, microcontroller unit made further data processing, data averaging in 10-minute intervals and data formatting into a format understandable by the central server agent. At the beginning that was the XML format, but to minimize the activity of embedded microcontroller unit at the end direct agent communication and exchange of variable values was adopted. Agent deployed in the central server communicates with an embedded device over the network, asking for formatted data by HTTP request. It is important to emphasize that agents communicate using the standard FIPA ACL (Agent Communication Language). By using this approach time delay between data samples was minimized because each agent runs in its own thread and doesn't have to wait for another one to finish before activation. Connecting new sensor nodes to the existing system requires only starting new instances of the necessary agents to the running agent platform, or even new agent platform which is a part of the same system.

The same procedure was used for image data collecting. The video part of the monitoring unit had pan/tilt/zoom-controlled heavy-duty video camera and an embedded video Web server. The embedded video Web server was responsible for image digitalization and compression in JPEG format. Each camera had a number of preset positions to cover the surroundings completely. The Camera Agent on the central server was responsible not only for image collecting but also for moving the camera to an appropriate preset position by adjusting camera's pan and tilt angles. Also in this case all communication between the Camera Agent and the video Web server was done by HTTP requests.

The fundamental system architecture is shown in Figure 5.

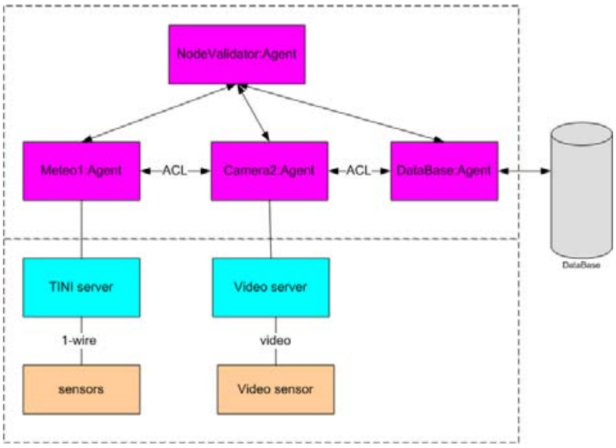


Figure 5: The fundamental system architecture

## 4. Multi agent system for data validation

Collected and archived data can be used in various applications. iForestFire uses meteorological data for user information, forest fire danger index calculation, and in alarms creation and post processing. It is of great importance that data is accurate, and up to date.

After the data is collected it needs to be verified. Special kind of intelligent agent called ValidatorAgent is created for accomplishing this task. ValidatorAgent checks physical presence of each sensor in sensor node, and functionality of a sensor in term of is the data given probable, according to past values, other near readings, daily and yearly trends and so on. This agent uses rule base written in JESS rules language and uses JESS engine in reasoning and inference.
With this, the system is given a common sense. [16]. Common sense reasoning is broad but shallow reasoning over a large number of rules.

The rules are short and kept simple, but the knowledge base consists of large number of rules, and can be extended after test period.
The visualization of the typical error that can be detected and visualization after validation and pronouncing an error value and excluding it from the archive can be seen in figure 6.

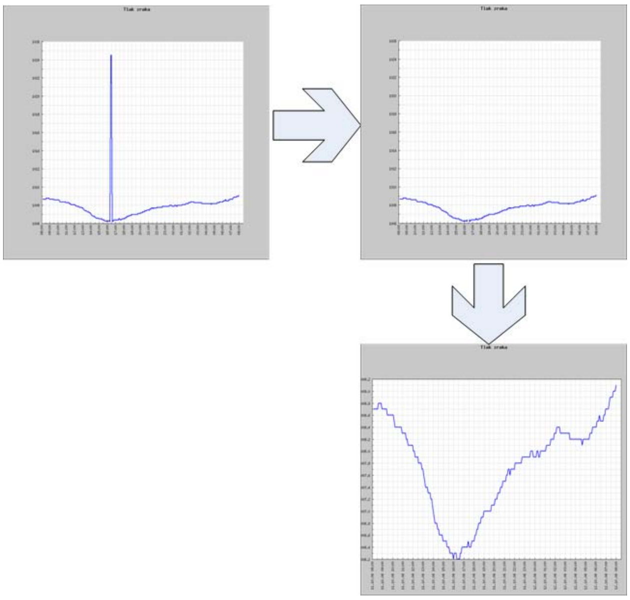

Figure 6: Atmospheric pressure chart, before and after excluding error values and after adjusting the scale

## 5. Conclusion

In this paper we presented a unified architecture for data collection and verification ofer a environment monitoring sensor network. The architecture is intended to be used over sensor network consisting of large number of sensors distributed in space. An hierarchical architecture of sensors in the sensor and networking layer help us to get better control over sensors, assigning one collector agent for each master node. Validating agent is used for validating overall sensor node data.
This part of the iForestFire system helps human operators the most, giving them only alarms if a malfunction in sensor network is detected, so there is no need for their constant attention.
The same architecture can also be used in implementation of any kind of monitoring with sensor network of any kind.

## 6. References


*[1] Chong C., Kumar S.P., "Senor Networks: Evolution, Opportunities and Challenges", Proceedings of the IEEE, VOL. 91, No. 8 Aug 2003*

*[2] www.wikipedia.org*

*[3] Johannes Gehrke and Ling Liu, "Sensor-Network Applications," IEEE Internet Computing, vol. 10, no. 2, 2006, pp. 16-17.*

*[4] http://www.ni.com/dataloggers/*

*[5] http://www.monitorsensors.com/*

*[6] http://www.ysi.com/*

*[7] http://www.deltatrak.com/*

*[8] Rajasekar, F. Vernon, T. Hansen, K. Linquist, J. Orcutt, Virtual Object Ring Buffer: A Framework for Real-time Data Grid", HDPC Conference 2004.*

*[9] Nodine, M., Fowler, J., Ksiezyk, T., Perry, B., Taylor, M. and Unruh, A. (2000), "Active information gathering in InfoSleuth", International Journal of Cooperative Information Systems 9(1-2), 3-28.*

*[10] Athanasiadis, Pericles A. Mitkas , Ioannis N. , An Agent-Based Intelligent Environmental Monitoring System, Management of Environmental Quality, An International Journal vol.15,no.3,pp.238-249, 2004. Emerald Publishers.*

*[11] Tierney, B., Crowley, B. et al. (2000), A monitoring sensor management system for grid environments, in "High Performance Distributed Computing (HPDC-9)", American Meteorological Society, Pittsburg, Pennsylvania.*

*[12] Alonso-Betanzos A et al., An intelligent system for forest fire risk prediction and fire fighting management in Galicia, Expert Systems with Applications 25, 2003, 545–554*

*[13] San-Miguel-Ayanz, et al., Towards the integration of spatial information on forest fires: The European Forest Fire Information System (EFFIS), New communication and information technologies in forest fire prevention and suppression, 2001, Kalamata, Greece.*

*[14] Llinas, J., Hall, D.L., An introduction to multi-sensor data fusion, Circuits and Systems, 1998. ISCAS apos;98. Proceedings of the 1998 IEEE International Symposium on Volume 6, Issue , 31 May-3 Jun 1998 Page(s):537 - 540 vol.6*

*[15] "EYES – Energy Efficient Sensor Network", EU Research Project, 2002 – 2005, http://www.eyes.eu.org*

*[16] Push Singh, Marvin Minsky, and Ian Eslick (2004). Computing commonsense. BT Technology Journal, 22(4):201-210.*

*[17] D.Stipanicev, B.Hrastnik, Integral model for Forest Fires Protection in Split-Dalmatia County, FESB Report for Split-Dalmatia County, June 2003 (in Croatian)*

*[18] D.Stipaničev, M.Štula, Lj.Bodrožić, Multiagent Based Greenhouse Telecontrol System as a Tool for Distance Experimentation, IEEE Int.Symposium on Industrial Electronics, ISIE - 2005, Dubrovnik, 20-23.06.2005.*

*[19] M.Štula, D.Stipaničev, Agent Based Methodologies in Distributed Control, Proc.of Int. Conf. CEEPUS Summer School Intelligent Control Systems (ISBN 80-214-2976-3), Brno, Czech Rep. 29.08.-11.09.2005. pp. 222 – 228*

*[20] Lj.Bodrozic, D.Stipanicev, M.Stula, "Agent Based Data Collecting in Forest Fire Monitoring System", Proc. of 2006. Int. Conf. SoftCOM 200 , Split, Dubrovnik, Sept. 29.-Oct.1. 2006*

*[21] S.Bussmann, N.R.Jennings, M.J.Wooldridge, On the identification of agents in the design of production control systems, Agent-Oriented Software Engineering, Springer-verlag, pp.141-162, 2001.*

*[22] M.Woldridge, N.Jennings, Intelligent Agents:Theory and Practice, Knowledge Engineering Review, Vol.10, No.2, Cambridge University Press, 1995.*

*[23] TINI – Tiny Internet Interface - http://www.maxim-ic.com/TINIplatform.cfm*

*[24] JADE – Java Agent Development Framework - http://jade.tilab.com/*