Information and knowledge sharing in a distributed system: application to environmental monitoring system

V. Di Lecce[1] and V. Piuri [2]
[1] Dept Electrical and Electronics Engineering, Politecnico di Bari, Italy
[2]Dept Information Technologies, University of Milan, Italy

I. EXTENDED ABSTRACT

The air quality monitoring systems are increasing in number and complexity all over the world due to an expanding consciousness about the value of a high-quality environment and the specific Laws and Acts. The interest and the attention devoted to the environmental thematic, to monitoring and to the control activities about air quality are in fact growing quickly.

Many Government Agencies for environmental protection (i.e., the Italian ANPA) are imposing the implementation of environmental monitoring stations located in a wide geographic area, in order to:

- supply significant real data;
- document the air quality in time;
- characterize the causes that determine the atmospheric pollution;
- foresee the biological effects due to exposure to the pollutants in the long term.

These systems are typically based on many distributed processing units, devoted to sensors data acquisition and storing. The high-level processing and analysis tasks are centralized.

A natural evolution consists of using the distributed artificial intelligence to extend the abilities of data analysis, prediction and extrapolation. Agents and Multi-Agent Systems (MAS) are widely discussed by researchers as a powerful way to implement artificial intelligence [1], also based on Marvin Minsky intuitions.

In practical application, agents are usually considered as a self-directed program object which have its own value system and the means to solve the assigned problem for subtask each one independently and then communicate its solution to a greater problem solving process (MAS), either on its own initiative or on request from other agents [2,3].

In a conceptual schemes due to Qiao and Zhu [4] it is possible to recognize in an agent five components:

- **Perception,** a channel for an agent to receive information from the external world.
- **Effector,** an interface for an agent to modify or influence the state of the MAS
- **Communication,** a mechanism for an agent to exchange communication with other members in the agent society.
- **Objectives,** a list of roles for an agent to play.
- **Knowledge processor,** a knowledge base system that stores and processes the necessary knowledge for an agent to play the role the MAS has designed for it.

To create MAS we can layer different functions and components needed to solve the problem (e.g., [5]).

The basic recognizable functions of MAS can be arranged in five layers, as in the follow:.

- **User Area:** users can be both human and different external systems that require accessing to the MAS services. In this area are interfaces video masks, if human user wants to interact with the MAS; there are communication ports too, if another external MAS require interactions.
- **Interface Area:** in this area are present one or more *Interface Agents* that can interact with the users. The main role of this area is to translate messages from external world (with a own ontology) to the MAS intermediating messages typically based on an ACL [6], [7] [8]. Both the ontologies are characterized by the own cardinality (n_{IO}=internal cardinality, n_{EO}= external cardinality) and by an own interpretation of the adopted terms. So, during a communication the following cases can have:
    - $n_{IO} < n_{EO}$, not all the required services can be satisfy by the MAS, because the message isn't completely not understood;
    - $n_{IO} > n_{EO}$, not all the services of the MAS are usable by the requiring;
    - $n_{IO} = n_{EO}$, there is a perfect correspondence for all the services offered by the MAS.
- **Brokerage Area.** Two different agent types are present in this area: *broker* and *coach*. The agents don't communicate directly with one another, but they do it through intermediaries called broker [9],[10]. The *Coach Agent* [11] is necessary when competitive agents are in the environment. It chooses among different agent answers to give the best result.
- **Analysis Area** is the application core system. The agents of this area allow satisfying the MAS computational goals. This is possible by using techniques of cooperation and/or competition among the agents [18]. Agents manipulate and/or collect information from many sources. The information agents would have to be endowed with the capabilities of knowing where to look/try, how to find the information and how to collect it.

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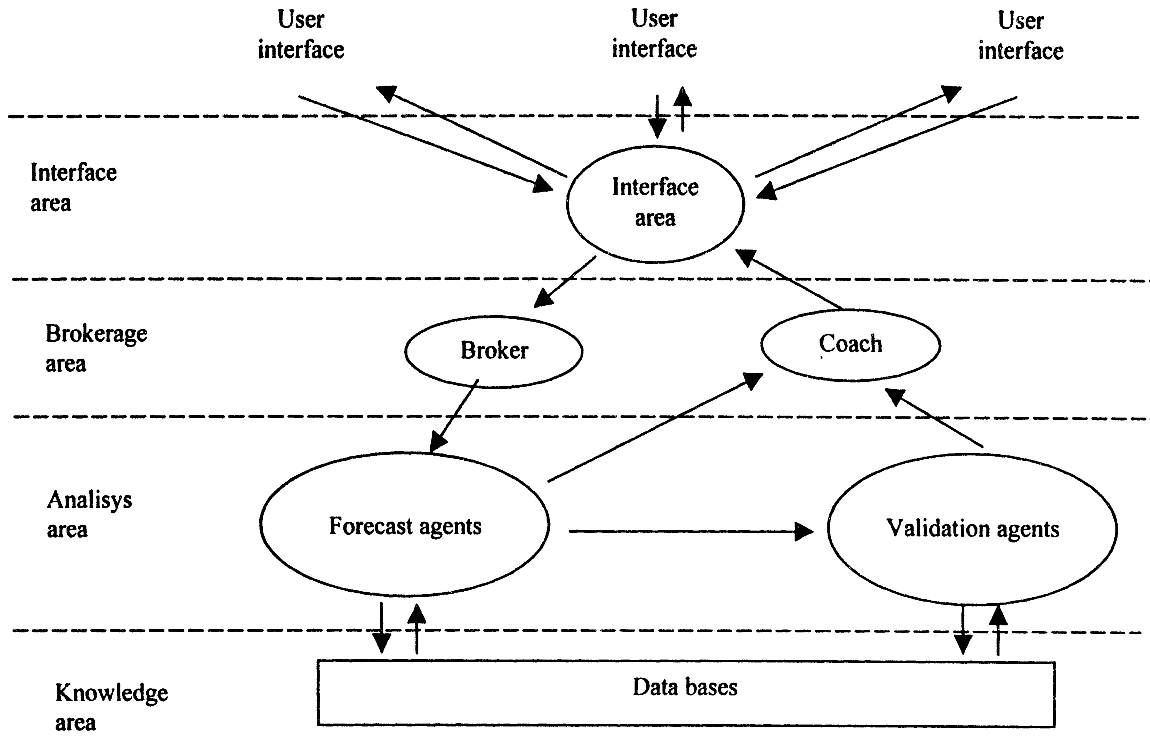

Fig1. Multi Agent System architecture for environmental monitoring system

- **Knowledge base system.** In this area are all the system databases that the agents use for achieving their objectives, or that they write for increasing their knowledge.

In the application to the Environmental monitoring, the *Analysis Area* contains two agent classes:

- *Forecast agents*: this agents have their own knowledge, based on a forecasting model, known in literature and characterizing them. Each *Forecast agent* applies its analysis method, starting from the raw data previously acquired by the sensors. These agents extract their trend curve. The well suitable response is selected by the *coach* in the Brokerage area. The *coach* records the differences among the measured value and the trend of every *Forecasting* agents, updating a table of reliability. This kind of communication is an exchange of information, and the knowledge of the environment increases. In this case, reactive decisions become cooperative [10], [12].
- *Validation agents*: the actions on *forecast agents* might be myopic in this approach. For this reason a temporal validation, followed by a spatial one is performed. This justifies the presence of the two agents, *Temporal-Valid* and *Spatial-Valid* agents, in the system. The last two agents are collaborative because the unique goal is the data validation that is divided in two tasks. *Temporal-Valid* agent compares raw data with estimated data (extracted using one of the previously explained *forecasting agents*). If the difference is contained in a tolerance range, data is defined as valid. An expert (for example a chemist) defines the tolerance range. Another agent checks no-valid data: *Spatial-Valid*, that tries to validate data, using the knowledge of the geographic position in which sensors are positioned.

In the full paper five layers stratification of MAS is presented. In particular, the use for optimizing the different agents activity and cooperation as inspired by [13] is discussed. A similar approach has been used to realize an environmental application presented in [14, 15].

Inside the proposed MAS, the number of the layers, the type of agents, and their position are due to the results of an accurate analysis of the general MAS characteristics. Moreover this approach implies ontology integration.

The result of Simulink-Matlab simulation should be presented showing good result both in terms of MAS architecture, both in terms of environmental monitoring application.

II. References

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