# A Prototype of an Active Decision Support System, based on an Abstract Intelligent Agent Architecture

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***Abstract***
The paper presents an intelligent-agent based approach to the modelling of an active Second-Generation Decision Support Systems. Our project CIPRODS (Civil Italian PRotection Overview and Decision-support System), is aimed at providing intelligent computer support during management of the large industrial accidents that involves intervention of Decision-makers from the Italian Civil Protection Operation Centre. The prototype system is composed of three main functional modules: Diagnostic, Predictive and Decision-Making. The model of the Abstract Intelligent Agent (AIA) is employed for the Decision-Making functional module design. The DSS is based on the AIA architecture composed of three types of subsystems: Domain system, Preferences system and Knowledge system, which can be configured on different abstraction meta-levels. In the above context we used the decision-making process as a dynamic property of AIA architecture.

## 1. Introduction

As consequence of the increased complexity of present days catastrophes, uncorrect decisions by emergency-managers can multiply human, economical, and cultural losses, instead of mitigating a disaster situation. Therefore, ***in the disaster mitigation, the importance of the emergency manager quality is still increasing.*** On the other hand, Artificial Intelligence Technology explosive growth enables the improvement of managerial decisions in a significant manner.

The design of Intelligent Decision Support System for Emergency Management (EM-IDSS) is closely related to our understanding and the capability of modelling of the concepts: *decision making* and *intelligence*. Both are closely related to the *intelligent-agent* technology currently being developed in software engineering and they will be explained in this paper in the framework of an abstract intelligent agent. On the other hand, the emergency management decision-making is a real-world activity where inference processes are strongly based on experts' qualitative and distributed knowledge, on an assessment of incomplete and uncertain information, and on a reasoning among many abstraction levels.

In this paper, we deal with the intelligent-agent based architecture of EM-IDSS and managerial decision-making. This novel approach is now under development in the framework of the ENEA's R&D activities focused on IDSSs for industrial emergency management[1].

The work is a continuation of our research presented in the our previous papers, for example (Gadomski, 1993), (Andersen et al. 1993), (Balducelli and Gadomski 1993), and (Balducelli et al. 1994). The general concept of IDSS for emergency management and functional specification of a system were presented at the TIEMEC 1995 Conference (Gadomski et al. 1995). In this paper, we demonstrate how using *Abstract Intelligent Agent* (AIA) framework, it is possible to define a generic intelligent-agent based decision-support module for EM-IDSSs. In the current phase of the IDSS development only this module is considered "intelligent".

## 2. Background and Project Goal

The actual trend in the emerging software technology is to produce systems that are more **active** during the interactions with its users. Many approaches and strategies are currently used and tested in this research field, but probably the most fruitful technology, experimented worldwide is **intelligent agent technology** based on, so called, **multi-agent approach.** Its main purpose is to distribute heterogeneous problem knowledge and management strategies among autonomous agents assigned to the tasks defined in different knowledge domains and on various abstraction levels.

The aim of project is to give a concrete contribution to the development of intelligent agent technology and to apply it to the design and implementation of **Active Decision Support Systems** to be used by the emergency managers during large-scale industrial emergencies. A central goal of our project is the provision of facilities which allow active decision support systems for emergency management to be rapidly constructed and supported within the context of iterative development. In such a context, Active Decision Support Systems (ADSS) based on recently developed software paradigms and technologies (various intelligent agent technologies) should, in the near future, not only provide data selected according to situation

[1] The activity is performed in frame of **MINDES** (Bologna, Gadomski,1996) which is the umbrella program that unifies the past ENEA's experience, in the field of emergency management and new information technologies, with the present and future activities. The program is focused ***on reducing the probability of human managerial*** errors during decision-making. It defines a strategic scope for various ENEA research. The MINDES program has been recognized as the italian contribution to the G7 "**GEMINI** : Global Emergency Management Information Network Initiative".

assessment procedures, but also to previously defined emergency plans. One of the serious difficulties in the design of DSSs is the necessity of acquisition, representation, and structuring of the problem knowledge in order to implement it in active autonomous software units.

Independently of the numerous realizations of software agents by software industry (Guilfoyle 1994), (Harmon 1995) and research efforts, see for example (Comm. of ACM 1994), (Wooldrige and Jennings 1995) and (Shoham 1993), uniform theory of intelligent agents is not developed yet. Various new approaches to the software agents modelling have been proposed. In this context we demonstrate a domain-independent conceptualization of an intelligent agent architecture which is based on **TOGA**, Top-down Object-based Goal-oriented Approach (Gadomski 1993), (Gadomski et al. 1994) (Gadomski et al. 1995). This approach is a generalization and integration of various concepts of the structural design methodology with intelligent system concepts and technologies. Consequently, it assumes an ontology which is based on the model of an Abstract Intelligent Agent and on its goal-oriented point of view. The choice of Intelligent Agent Technology has resulted from individual experiences and from a deep evaluation of the current trends in the market of software technology development. *Intelligent agents represent the next generation beyond object-oriented software (* Guilfoyle, Warner,1994) - *objects which act autonomously in a certain domain, and perform tasks defined by the human user.*

In computer science, the concept "agent" is put in many categories but, in general, an **intelligent software agent** is a class of software functional which can change its own intermediate goals and may learn.

A **software agent** is a special software module assigned to predefined external tasks, having execution autonomy and reacting capability; the design of a multi-agent software system utilizes these primary software modules which cooperate together in different domains.

Some possibilities of agents' clustering are analyzed in the literature, see, for example (Singh 1994) and the papers in (Lesser 1995). In general, the integration of simple agents into one architecture enables to development of intelligent agents with learning capability, designated to cooperation with human users and with roles depending on agent *knowledge, preferences* and *ontologies* (according to the AIA model).

- ***Agent*** is "... an ***autonomous***, self-contained, **reactive**, **pro-active** computer system, typically with a central locus of control that is able to communicate with other agents via some ACL (Agent Communication Language). More specific usage means a computer system that is either conceptualized or implemented in terms of concepts more usually applied to humans (such as beliefs, desires, and intentions)."

- ***Agent-Oriented Programming*** - is an approach to building agents, which proposes programming them in terms of mentalistic notions such as *beliefs, desires* and *intentions*

*(Wooldridge 1993)* These definitions are closely related to cognitive engineering and functional understanding of "intelligence".

-***Intelligent agent*** (IA) is autonomous, task-driven, software component with capability of learning and reasoning about its own knowledge and preferences on different meta-reasoning levels (Gadomski,1993).

**3. Developed Prototype**

The prototype of the system is developed in frame of the CIPRODS (Civil Italian Protection, Overview and Decision-support System) project. It is the first ENEA's prototype which employs certain TOGA paradigms and is targeted on the needs of the managers from the Emergency Operation Centre at Italian Civil Protection (ICP). Our aim has been to analyze the domain of intervention of ICP and to use new tools in order to enhance the capability of ICP for fast recognition of industrial disaster, and to provide the possibility of fast interventions in order to reduce maximal negative consequences of the disaster on the population and the environment. A system approach to integrate the new technologies, as CBR (Case Base Reasoning) and other software products ( such as GIS) has been used.

The ICP activity mainly concerns the continuous supervision of the national territory. Its first task is to recognize dangerous situations that could affect the safety of people and the environment, and which need interventions of local and national emergency management organizations. The second task is to start the appropriate emergency procedures related to the support and coordination of various emergency operators. Therefore, ICP must have continuous and as precise as possible, information about the past states, current developments and possible consequences of the accident.

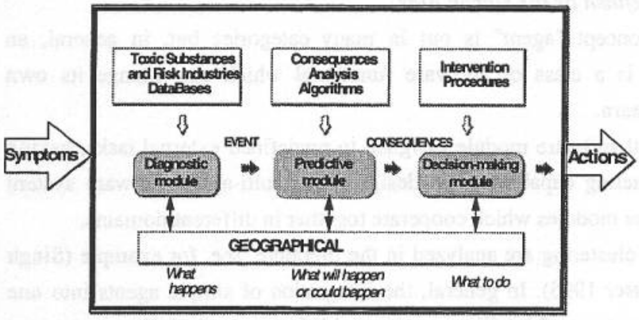


Fig.1 Functional Architecture of an Active Decision Support System

During the knowledge acquisition phase, we have recognized the following basic ICP users requirements :

1. Off-line and real-time interactions with the system. The data about current events are entered manually to the system. They are obtained from the national territory by classical communication tools, such as telephone, fax, radio.

2. Support in the ***recognition of toxic substances*** in the suspected zone, on the basis of received ***symptoms.***
3. Support in the ***identification of the industry*** which is a source of emergency, i.e. identification of place and character of the incident which is a cause of the emission of the toxic substances into atmosphere, water, or the soil.
4. Support for the ***supervisory actions*** adequate to meet ICP's responsibilities and recognized situation.

The first prototype of an active DSS is divided in three different modules: Diagnostic, Predictive, and Decisional.

The **Diagnostic module** design goal is a recognition of the cause of the accident. It starts from emergency symptoms acquisition and employs the **CBR** (Case Base Reasoning) method for the identification of the toxic substances and of the place of emergency source. Information about an emergency symptoms are received from different sources (police, health service, people,etc.) distributed on the national territory; an operator introduces the symptoms' description in natural language into computer.

The **Prediction module** design-goal is a consequence searching, i.e. the indication of maximal and most probable dangerous events which could be caused by the precedent and currently recognized emergency states. On the user request and according to the entered data, it generates hypothetical scenarios of emergency development and propagation. The module should also include a ***what-if*** simulation

The **Decisional module** is the key component of the system. It is now under development. The AIA architecture is the carrier of the decision-making processes. An intelligent agent generates and evaluates a decision. Its goal is to suggest to the operator possible alternative actions suitable in the current, particular situation. Using the domain model and available criteria, the Decisional module assess the level and the type of possible risk, as well as indicating appropriate interventions using emergency instructions or procedures. The decision-making agent requests information from the Diagnostics and Prediction Modules. It uses data from Geographical Databases and knowledge from an Intervention Procedures Base.

## 4. Abstract Intelligent Agent Architecture

In the TOGA approach, a general architecture framework and basic reasoning mechanism of an *abstract simple agent* (ASA) and an *abstract intelligent agent* (AIA) are defined. The construction of these agents is founded on the following basic concepts:

- *information,* denoted by **i** or *inf*, which provides data how the situation looks (before, now, in the future) in the agent domain of activity;
- *knowledge,* denoted **k,** is a tool for data processing, it gives the answers how the situation may be classified and modelled, and what is possible to do by the agent.

• *preferences,* denoted **p,** is a set of rules which determine what is more important for the agent in its intervention domain.

• *goal,* denoted **g,** is a state of the domain of activity which should be achieved.

All these concepts : - have *object-property,* i.e. can be aggregated and decomposed according to the abstract objects' framework, - are relative, and always refer to a predefined d-o-a (domain of activity) which is real or abstract, and which is unique source of information .

One of the foundamental TOGA assumptions is that **i** , **p, g, k** are defined all together by generic reasoning processes executed by the following three functional systems:

- the ***Activity-Domain system,*** **ADS,** consisting of a representation and a basic mechanism that every agent uses for the conceptualization, decomposition and modification of the external reality from its own point of view.
- the ***Preferences system,*** **PS,** is a basic mechanism that every agent uses to generate *the intervention goals.* It is activated by new information coming from the Activity Domain.
- the ***Knowledge system,*** **KS,** is a basic mechanism that every agent uses to generate actions for the modification of the Activity Domain according to the current intervention goal. ASA has fixed knowledge and preferences, but choice of its goal depends on current information.

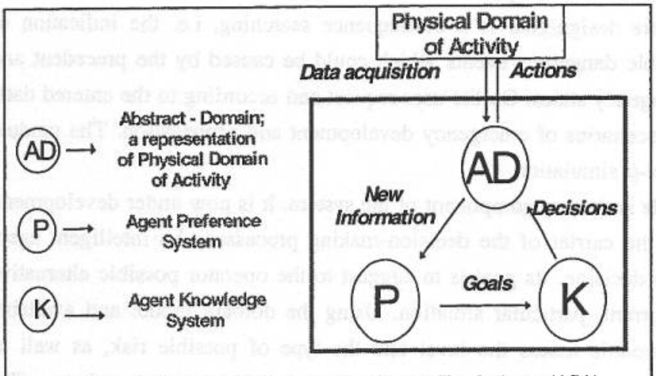


Fig.2 Functional Architecture of the Abstract Simple Agent (ASA)

More flexible is the Abstract Intelligent Agent(AIA):

**AIA *is an abstract entity which is able to reason about, and to modify its own knowledge and preferences (i.e. goals).***

AIA consists of the hierarchical pyramidal structure of ASAs. For the modifications of *Knowledge* and *Preferences* of the basic ASA, these two systems must become domains of activity for two ASAs located on the higher *meta-level.* Every next meta-level may include more ASAs. This structure is illustrated on the Fig. 3.

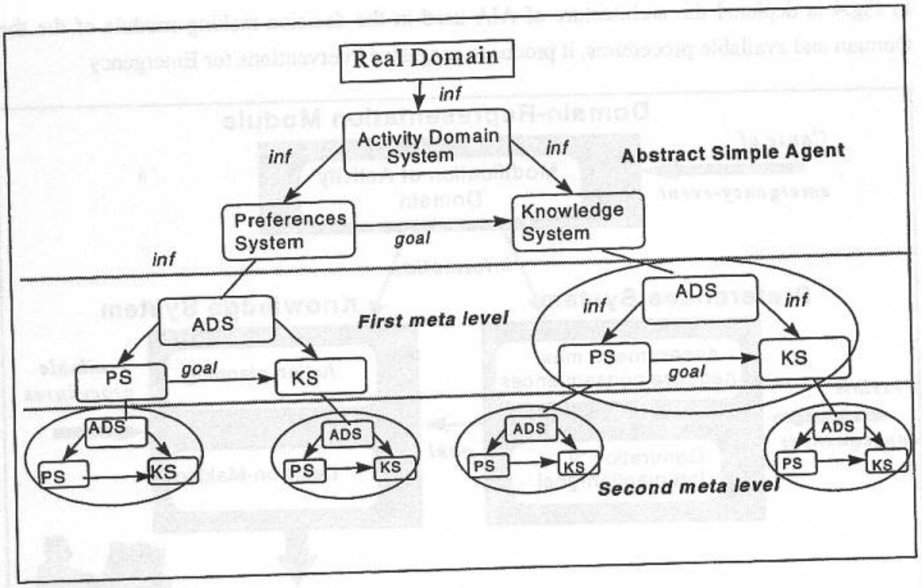


Fig.3 Multi-level Architecture of an Abstract Intelligent Agent

In this way, we can formally present the generic representation of learning and tutoring proceses (Gadomski, 1997)

## 5. AIA Implementation Environment

An emergency event modifies the Domain of Activity. This new information is processed by the Preference System that requires an assessment of the possible consequences of the emergency event. Then PS, using the criteria stored in its rule-base, generates an intervention-goal, represented as a desired state of the Domain.

The Knowledge System is activated by the intervention-goal; using information coming from the Domain and available procedures, it produces suggested interventions for Emergency Managers. These interventions can be realized as planned actions, i.e. as an ordered sequence of the available procedures. The overall system should act as an Artificial Intelligent Agent helping the human staff in management of the industrial emergency.

The implementation environment is the ILOG development tools (ILOG 96).

The Ilog Rules is used as a tool for the implementation of the preferences rules in PS and Knowledge Bases in KS.

The graphical interface for the editing of the ADS, PS and KS is constructed using Ilog View.

In Fig.4 is depicted the architecture of AIA used in the decision-making module of the the Domain and available procedures, it produces suggested interventions for Emergency

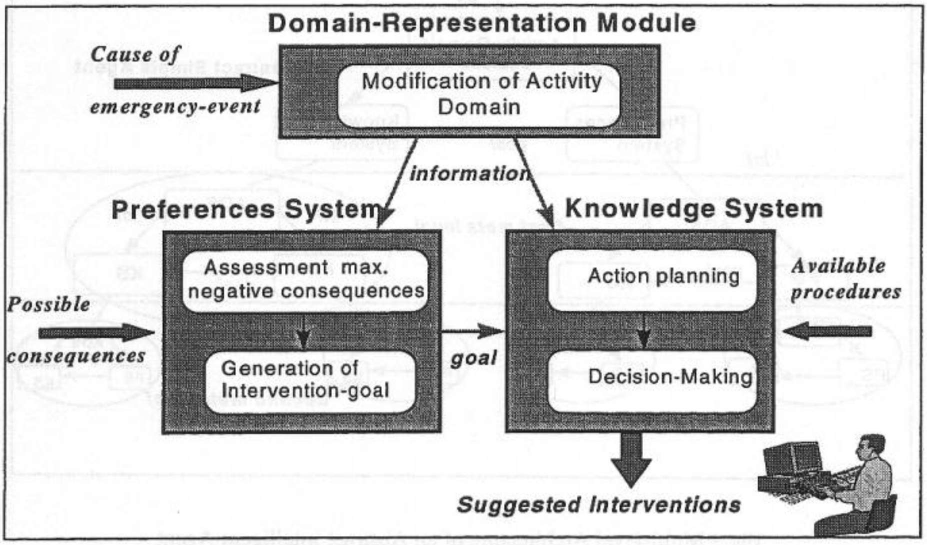


Fig.4 Decision-Making Module based on Abstract-Intelligent-Agent Architecture

**Conclusion**

The IDSS for EM should be based on an intelligent software agent. The following roles of such an agent can be distinguished by:

- an intelligent interface between classical DSS and its user, which includes searching of data according to the user's requests .
- support in the coordination of the user's activity according to the emergency plans, for example controlling their milestones, as well as an intelligent agenda.

A formal abstraction from the physical carrier of AIA enables the developer an explicit division of the AIA's functions between human decision-maker and a computer support system. Such division is based on the previously discussed Decision-making model.

The following structured emergency manager knowledge must be entered into architecture frames of AIA:

- emergency situation models,
- emergency management strategies,
- emergency cooperation constraints, i.e. individual and coordinated group decision-making under high risk, stress and time constraints.

The above knowledge has been partially investigated in frames of the EU ISEM and MUSTER projects (Balducelli et al. 1994), (Andersen at al., 1993).

Currently, in the CIPRODS project, our effort is concentrated on allocation of the generic decision-support functions and the domain-dependent knowledge and preferences, to the intelligent agent architecture.

In the next step we intend to allocate all the functions of the CIPRODS modules to cooperating autonomous intelligent agents. Summarizing, applications of the framework of Abstract Intelligent Agent seems to be a very promising for passing from the generally used *menu-driven paradigm* to the *goal-driven paradigm*, namely, to an intelligent, personalized (role tailored) decision assistant of emergency managers.

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