COMPUTER AIDED TRAINING FOR COOPERATING EMERGENCY MANAGERS: SOME RESULTS OF MUSTER PROJECT

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Abstract

The paper presents italian results of the CEC Environment Project MUSTER[1] (Multi-Users System for Training and Evaluating Environmental Emergency Response). A novel conceptualization framework for the computer aided training of cooperating and coordinated emergency managers is discussed. Two basic functions of the computer support system have been defined: - a simulation of an emergency environment and the activity of emergency organization., - a support to the instructor functions. The trainee model is based on the functional architecture of an abstract intelligent agent. An application of the concept of intelligent agent enables to represent the cooperation between emergency managers in multi-agent system, and to analyse causes of their errorneuss decisions.
The architecture of the prototype system is described. A concrete example of its applications is referred to the benchmark represented the emergency state and its evolution at the Genoa Oil Port, caused by an explosion and firing of an oil tanker.

1 Introduction

Management of large-scale emergency is a complex high-risk task where human managerial errors can create unforeseen losses and irreversible consequences. The efficacy of many managers acting together depends strongly on the quality of the emergency managers training.

To maintain and to improve the efficiency of such activities, emergency organizations execute periodically territorial trainings and exrecises: these exercises are sufficiently realistic but they have a very high costs, are difficult to repeat and to analyse in the real time. In addition, in this way, not every hypotheticaly possible accident may be simulated.
An other training method is a computer based training. It exploits the simulation capability of computer systems. Up to now, this method has a low level of realism but the costs are lower and it allows to explore and deeply analyse wide range of dangerous situations. Therefore, the applications of advanced information technologies in support to the emergency management training are today strongly investigated.
One of the key problems of EM (Emergency Management) is an efficient cooperation of different emergency managers in frame of EM-organization.In this paper it is conceptualized as a multi-agent hierarchical organizations.
In such context, a computer added collective training is aimed to improve the coordination level inside multi-agents organizations, to evaluate emergency procedures, and to verify effectiveness of the utilized tools. In fact, in the situations characterized by a high environmental risk, like industrial ports and other geographical areas associated with high energy density, the emergencies are managed by the different types distributed national and private authorities.
Every actor on the emergency domain scene has his own responsibility, duties and pre-defined intervention procedures but, very often, their execution is not in agreement with the goals of mutual coordination of the emergency.

[1]MUSTER is a CEC founded Project in the framework of the ENVIRONMENT Programme.

Now (see for example Tiemec'94 and Tiemec'95 Proceedings) it is recognized that the efficiency of an emergency management organization mainly depends on the coordination of various autonomous intervention units involved in common actions.
The complex coordination function requires a new identification and planning attempts to the emergency management (EM) activities.

For this purpose, besides to provide scenario specifications, the Italian participants to the MUSTER project [Ref.1], have developed a computer prototype for a high risk zone (an Oil Port in Italy) based on a true emergency scenario occurred some years ago (a tanker explosion in the oil port area).
The prototype architecture consists of a network of personal computers. In particular, the demonstrated training session is composed of a supervisor and two trainees with their workstations.
Two basic functions of the computer support system has been defined.
The primary is to simulate emergency management conditions, i.e.:

- to furnish visual and textual information about the current state of the emergency domain,
- to pass messages from and to the e-managers, and
- to effectuate agents (manager) actions.

The second refers to the support to the training supervisor functions.
The training model employes all the above mentioned tasks in one conceptual multi-model framework.
The supervisor has the task to plan the training session (this can be done long time before the training session), to illustrate the session, to control the exercises execution, and to evaluate the results. The trainees, through their workstations, perform actions on the simulated scenario. In the demonstrated sessions one trainee represents the on-field coordinator (the coordinator agent operating near the accident), the other trainee represents the on-site coordinator (who in this case is the Oil Port director). The activity of the other actors of the emergency management are simulated by the computer system. The results of the training sessions are analyzed by their participants.
For such defined tasks a general model of an abstract intelligent agent as a role-independent decision-maker has been applied.
The specification of the Italian MUSTER training support system has been carried out through the analysis and definition of four main, interrelated parts:

1) a model of an emergency manager
2) a multi-agent cooperation model framework;
3) an emergency domain framework;
4) a multi-agent training-support system

Each of the four parts resulting from the above analysis and modeling activity provided a contribution to the conceptual background for the specification, design , implementation and application of the Italian MUSTER system.
In this paper we roughly describe our methodological approach and obtained results.

2 Model of Emergency Manager

2.1 Framework of abstract intelligent agent

The model of emergency manager applied in this work is based on a genaral framework of intelligent agent.
The concept of an intelligent agent has been employed in the following tasks of the italian part of the MUSTER project:

- modeling of the cooperation among emergency managers
- evaluation of the human errors during training sessions.

In the recent years the models of intelligent agents are strongly investigated (see the subject matter literature, for example [Ref.2,4,5]. Different, new approaches to the software agents, like a general idea of agents-oriented programming [Ref.3], and interactions of softbots (taskbots, userbots - the suffix "bot" is used for "software robot" [Ref.4]) in multi-agent systems , have been analyzed. In this context we have argued a domain-independent conceptualization of intelligent agent model employed in theTop-down Object-based Goal-oriented Approach (TOGA) [Ref.5,9]. This methodology contains three fundamental frameworks: *goal-oriented activity* of Abstract Intelligent Agent (AIA) , *domain of activity* (d-o-a) of AIA, *AIA model.*
The functional construction of agents is there funded on the following basic concepts:

information: how situation looks (before, now, in the future) ?
knowledge*:* how situation may be classified, and what is possible to do ?
preferences*:* what is more important ?
goal**:** what should be achieved ?

More precisely, these relative concepts always refer to a predefined domain of activity which is a source of

information. They are defined together with two generic reasoning processes executed by the *preferences system* and *knowledge systems.* The carrier of these processes is a triangle composed of :
abstract d-o-a, preferences system and knowledge system, it is called Abstract Simple Agent (ASA).
An Abstract Intelligent Agent (AIA) is composed of ASAs. The AIA definition:
AIA is an abstract agent which is able to reason about, and modify its own knowledge and preferences.
In this way AIA consists of the hierarchical piramidal structure of ASAs where every knowledge and preferences system is an abstract d-o-a for the next reasoning level (so called mete-levels) .
The generic cognitive reasoning schema is illustrated in the fig. 1; in the schema three different rule-based systems linked together are evidenced.

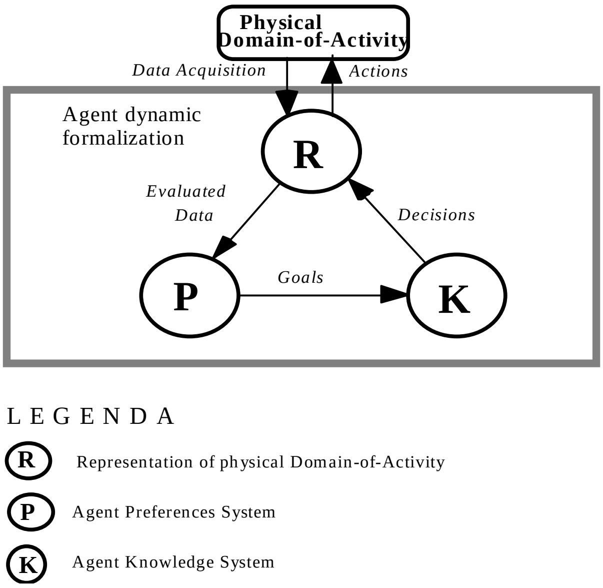

Fig. 1 Generic schema of agent conceptualization

The first one (R) contains the *representation,* in terms of objects and relations, of the physical domain on which the agent operates¸ it is the abstract domain of agent activity.
The second one (P) contains the agent's *preference system*. The current preferences depend upon the domain representation status and are used for *planning* the action's goals of the agent.
The third one (K) contains the agents *knowledge* involved in its reasoning and possible activities related to the represented domain .
As it is evidenced in the Fig. 1, the agent behavior is a continuous interaction and exchange of data among the three above defined rule-base systems. In fact data acquired from the real domain and represented in (R) are classified and evaluated based on the respective relevances. Evaluated data are furnished as input to the preferences system (P) that generates the agent goals on the domain. The generated goals activate adequated knowledge (K), it processes information that produces decisions or information represented in (R) and actuated by the agent.

2.1 Emergency Domain Model

Basic concepts

The physical emergency domain is a domain of the goal of emergency management activities. A mental image of this domain is the direct domain of activity of the manager, there he expects to achieve particular intervention-goals. The suggested LRS conceptualization framework is described in the Balducelli at al. paper [Ref. 7]. This framework has been used in the scenario generator module of the Muster training support system.
It is composed of three layers :
- Layout layer, LL
- Resources Layer , RL
- Scenario Layer, SL.

The SL and RL layers are mapped into LL. All of them are represented by abstract objects-relations networks.
LL includes the most static knowledge of the considered territory and its information are represented by more or less schematic maps.
RL includes the set of all the equipments, the components and the human organizations that are active on the considered territory.
SL includes the set of all the factors and events that may be considered on the territory in relation with the emergency management activity.

Layout Layer

LL represents the configuration of the territory under consideration for the emergency management activity. The main type of information included can be regarded as a set of physical constraints. A boundary is normally present in the layout layer to divide an in-site portion of the layout from the off-site one. The in-site layout is the part of the territory under the responsibility of the in-site manager (the Oil Port Authorities) normally not accessible to external people. The off-site layout is the external, public territory.

Resource Layer

With the term resource we refer to every equipment, system or component having some functions or goal inside the LL. A resource may be a technical resource or a human resource. For reasons of conceptual clarity an object-oriented approach seems a quite natural choice. A resource has the following general attributes: *goal*, *location* on layout, *vulnerability* level, *destructiveness* level, *degree of protection*. The contents of some of these, like goal and location on the layout does not depend on the scenario. The vulnerability level and destructiveness level values may depends on the type of scenario. Using this type of formalization the same physical resources (human or equipment) may be instantiated with different specific attributes depending on the situation and the scenario.

Scenario Layer

This layer contains all information related to the different kinds of factors and/or events that may emerge inside the domain and which can have some impact during an emergency situation. These factors can be classified as: *meteorological* factors, *population density* factors, *accessibility* constraints to accident location, *level of storage* of hazardous materials and other particular events. In general this layer contains all the information about events which can be hardly predicted in advance and that may influence the emergency evolution.

2.3 Preferences and knowledge systems

The modeling of the trainee preference and knowledge systems are not employed explicity in the design of the training support system, but they are important for sessions planning and for interpretation of their results.

The hierarchy of agent emergency preferences systems must be interpreted in frame of the generic architecture of AIA. They include structured domain dependent (variable) and domain independent (invariant) decisional criteria in frame of the hierarchical agent preferences. For such task a generic model of risk assessment and strategies of risk minimization are necessary. The preferences related to risk evaluation play fundamental role in AIA reasoning processes, therefore a generic *model of danger* and *risk* has been recently proposed in frame of the TOGA frameworks.

The preferences of a particular emergency manager are role dependent but, in general, can be represented as duties, situation-dependent instructions, and moral rules/constrains. Summarizing, the decision-making processes require risks and benefits evaluation in two basic contexts: direct intervention domain (emergency-domain) and communication domain. The last one concerns the same and heferences is the request of autonomous intervention in situation of the loosing of communication link betweenigher level managers. For example, one of the top pr cooperating managers.

A time-scale preferences should handle the real agent actions according to the time-constraints of the user possibilities and to the dynamics of emergency domain .

The agent's knowledge systems includes descriptive and operative knowledge. Descriptive knowledge includes emergency models' framework, and classification criteria. Operational knowledge includes production rules, intervention procedures, and emergency instructions.

The both types of these systems can be viewed as a “knowledge based systems” composed of rule-bases and inferential engines.

Of course this interpretation of human agents is very simplified but should be sufficient for the representation of the trainee professional roles.

2.4 Managerial activity of AIA

Definition:

In human organizations, *management* is an indirect control of real-world processes or systems through messages (included *data*, *tasks* and *commands)* addressed to autonomous intelligent agents with defined *roles* in the organization structure.

In the course of this work if we say 'Z manages X' it means that exists such Y which acts on X according to recieived messages, and Y is controlled by Z.

The organization is a distributed intelligent agent and in parallel, multi-agent system. It has internal and external roles usually determined by its *fundation goal* [Ref.5].

A fundation goal is achieved by activation of different, dependent on situation, intervention-goals.

Roles are specified by distinguished classes of tasks in terms of *responsibility*, *competence* and *disponibility*.

Internal roles of an organization unit are defined by interrelations with its neighbors cooperating nodes.

Management is only one of the roles of organization units.

Autonomy of actors is defined by their responsibility, competence and their current possibilities to acting.

Managerial activity of AIA is represented in the assumed methodology, by the conceptual interrelation between managerial intervention-goal (IG) and its carrier system, i.e. agent world. (AW).This interrelation is decomposed conceptualy into four layers:
intevention-goals layer, *tasks layer*, *actions layers*, and *world of AIA*.
A *task* is a specification what must be done in the real d-o-a in order to achieve a predefined intervention-goal.
An *action* is a specification how a task may be realized in current state of the AIA world.
For such reason, an *action* must depend on executor possibilities, and one *task* can be performed by execution of different alternative actions.
From the identification point of view, one selected action can be recognized as the carrier of different tasks. Tasks System (task scenario) is the executor independent and it depends on goal constrains .
Remark 1:
The definitions of tasks and actions require an adequate information, knowledge and preferences.
Remark 2:
An assumption of a formal conceptual frame of an abstract intelligent agent enables the explicit analyses of the decision-making processes of emergency managers.
The general model of AIA is employed in the next paragraph.

3 Multi-agent cooperation framework

Every intelligent agent (IA) which is a permanent or a temporal element of the organization of IAs is called *cooperating agent*.
One of the objective of multi-agents systems is to give solutions for problems and tasks inside complex environments exploiting the cooperation among more agents operating in a common intervention framework.
A set of agents grouped into an agent's *organization* have a *single objective* which is a top fundation-goal of the organization .
In the case of emergency management, this objective is:
a. to stop loss generation processes or to reduce them to the accepted values (according to assumed criteria)
b. to minimize total losses of human lives and materials.
c. to reduce the risk value to the level accepted in normal situation of the domain.

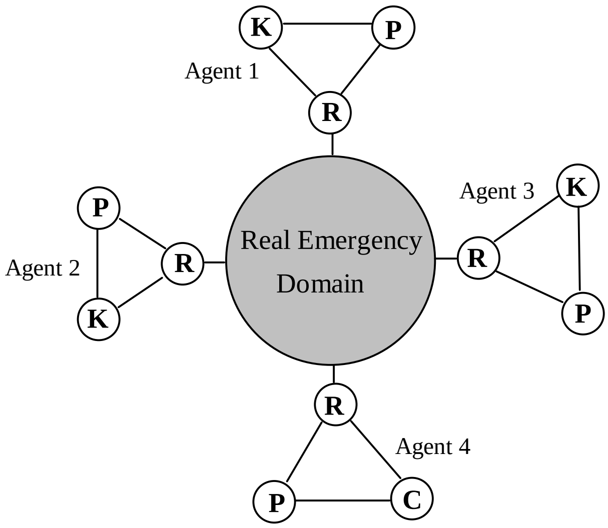

Fig. 2 More agents working on a real emergency domain

The fig.2 illustrates a possible configuration of agent's organization in relation with a real emergency domain. Every agent in this organization has an his own *representation* of different parts of the physical reality. This representation reflects his own *point of view* and his role-dependent *competence* and *responsability*. As an example, we can say that inside an Oil Port the Fire Brigades manager has a detailed representation, well defined preferences, and deep knowledge regarding to the antifire system whereas the tugboat manager is more competent about the berthing systems, and about the methods used for towing, etc.
A better coordination among agents implies to solve the following problems:
Conflict resolution: it is necessary when more agents, that have different intervention goals in the same domain compete for the utilization of the same resources.
Right allocation of resources: it is necessary when more agents have the same goal to be obtained in the same domain and, to reach the goal, have the necessity o allocate their resources in a coordinate way.
Tasks allocation among agents: it is necessary to obtain a good balance among the individual agent tasks in the considered domain in respect to the entity of their resources.

These agent's tasks and resources coordination problems are normally solved by so called *negotiation* among the agents. The negotiation process has first of all the goal to point out the mutual *dependencies* in respect to the common intervention domain, and then to allocate tasks using a mutual agreement.
Anyway, it is necessary to consider that this negotiation process could request a long time, that is not allowed during the emergency phase.
Also the practical exercising on the territory in many cases does not give an help to solve the agent coordination problem, because, due to the exercising costs, the resource's amount are normally predefined, and resource *variations* that could cause possible coordination conflicts among the agents, are not allowed. In other words during a practical exercise every agents exactly knows what will be his role and tasks, These exercises have mainly the goal to verify the *good working status* of the involved men and means but not the mutual agent's coordination.

A system capable to generate *simulated scenarios* of an emergency domain may be used for the agent's cooperative training support [Ref.6]. In this case, as illustrated in fig.3, the agents will be the trainees and a training supervisor will have the duty to prepare and execute the simulated scenarios.

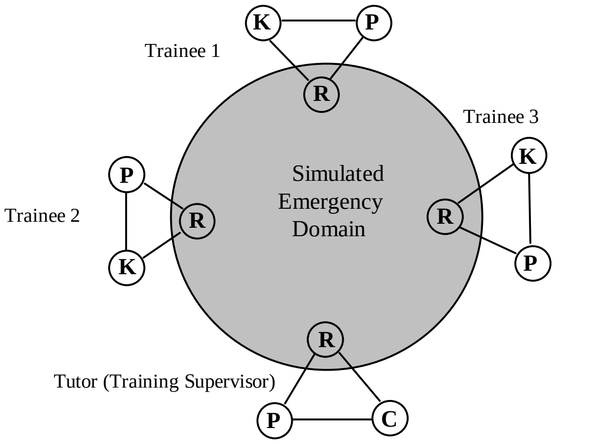

Fig. 3 Generation of simulated scenarios for cooperative training

As it is possible to see in the figure, the system gives to the agents the representation of the simulated emergency domain; so the agent's domain models are *included* or *mapped* inside the simualated reality. The supervisor gives the inputs, configures the events and the variables inside the simulated reality, while the trainees, to operate in the simulated environment, have to coordinate the respective preferences, goals and decisions that implies the action's execution during the emergency.

Finally, as showed on fig. 4, in the case of absence of a real training agent, the action simulation of the agent himself may be executed by the system using *computerized procedures* .

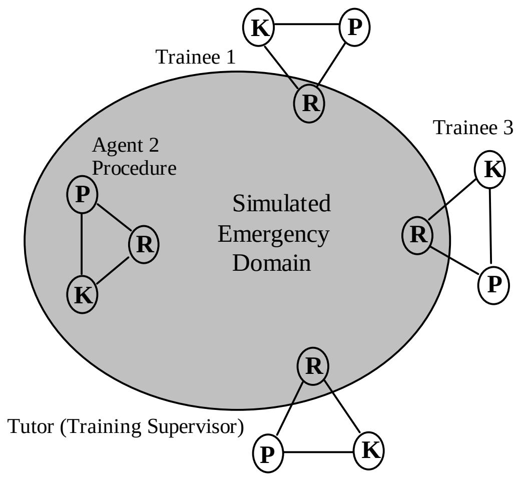

Fig. 4 Domain simulation and agent's simulation

The possibility to substitute a real agent behavior with a procedural model is useful to execute experiments aimed to evaluate the robustness of the emergency procedure utilized by the different emergency teams.
Since MUSTER is a multi-user training system, one of the main issues addressed during design was the definition of an appropriate reference model for cooperative working (CW). The model adopted, from the one hand provided the conceptual background to investigate and specify the general requirements of the MUSTER system, and, on the other hand, allowed to identify some components for the implementation of the system itself. The CW model adopted in MUSTER provides a description of the organizational structure, of the individual and cooperative tasks and of the intercommunication and behavior of the agents involved in the management of an emergency situation. Given the general objectives of MUSTER (i.e. training of coordination of emergency management managers and *not*, for instance, the operational training of emergency-fighting staffs like fire brigade etc.) only high level decision makers are considered as agents taking part to the cooperative

working structure. Based on this, the MUSTER CW model consists of two main conceptual elements:

- a description of the human emergency management framework
- a specification of the network of communication, decision-making and coordination of actions among the various actors involved.

4 MUSTER System Architecture

Two basic functions of the computer support system are defined.

The primary is to simulate emergency management conditions, i.e.:

- to provide visual and textual information about the current state of the emergency domain,
- to pass messages from and to the e-managers, and
- to effectuate agents (manager) actions.

The second refers to the support to the training supervisor functions.

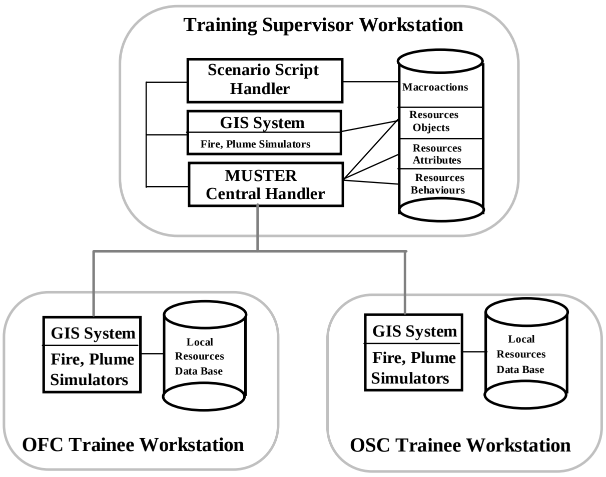

Fig. 5 Italian MUSTER prototype configuration.

The training model employes all the above mentioned tasks in one conceptual multi-model framework

As we can see in fig. 5, the Italian MUSTER prototype configuration is composed by three workstations (one for Training Supervisor and two for the trainees) connected together using the Windows for Workgroup . The different tasks comunicate each other using the Network DDE (Dynamic Data Exchange) facility.

The principal functional ities of the main system modules are described in details in the paper presented at TIEMEC'95 conference [Ref.10].

5. Developed Prototype

This prototype is used as a MUSTER demonstrator for the GENOVA OIL PORT domain. It was developed by ENEA and AUTOMA on the basis of the previous considerations. This demonstrator considers as reference scenario the domain of Genova Oil Port and the accident occurred in 1982 to the Hakouyu Maru tanker [Ref.8].

The considered domain in the demonstrator has been defined as ON-SITE domain. All the territory outside this domain is the OFF-SITE domain. We have assumed that this accident has involved only the ON-SITE domain, so the first trainee is the ON-SITE coordinator (the Genova Oil Port Director).

The ON-FIELD coordinator, the second trainee considered for the demonstrator, manages the operations near the accident location supported by the Fire Brigade Chief. All other trainees are simulated. It means that they can receive but not send messages and that their actions are simulated by the system or by the training supervisor himself. The training supervisor, that conducts the training session from his own workstation, is the third agent in the Genova Oil Port Demonstrator.

The system also supports the supervisor during the phase of session planning to generate session scripts. A session script can be conceptually viewed as a tree composed by nodes and arcs connecting different nodes as visualized in fig.6.

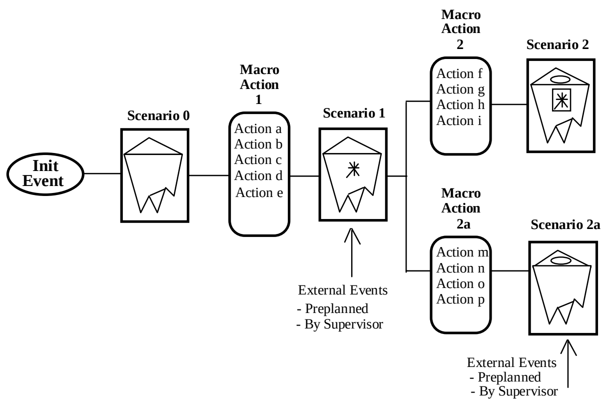

Fig. 6 The structure of the generic Scenario Tree

It is used by the Scenario Generator as a scenario tree where every node corresponds to a domain scenario, formed by the mapping of the different layers as previous defined. Every arc corresponds to the set of

actions that the trainee must execute to generate the n+1 scenario from the n scenario. So, the n+1 scenario may be seen as an updated status of the n scenario. The set of actions may be normally executed by one or more trainees so that they can be named composite actions or macro actions. The new generated scenario implements in the resource layer the updating (changing of state) caused by the macro action and, eventually, in the scenario layer the updating caused by the insertion of new physical events that may be preplanned into the script or inserted on-line by the supervisor.
In the actual prototype the planning phase is not demonstrated. So the prototype has an already designed script that corresponds to the Hakouyu Maru accident history [Ref.10], with some alternatives (different arcs at some nodes) in a set of defined point inside the history itself.

6 Training Session's Analysis

The trainees can execute operations on the simulated scenario: they can send messages to each other or to simulated trainees, they can allocate resources or decide ON-SITE/ON-FIELD operations (like the port evacuation, event notifications etc.).
The supervisor, at the begining of the training session, shows the accident scenario to every trainee, describes the initial situation and then decides when to start the training session. At this point the trainees, starting from first scenario of the scenario tree, perform actions in order to control the emergency propagation on the domain.
The supervisor, through his man-machine interface, may control the trainee decisions and actions. So, he can also decide to show them the new scenario, to stop the session when a particular condition occurs (for instance when a trainee has executed a very wrong action), to introduce a particular event on-line (an event not included in the scenario tree), to increase the difficulty of the training session etc.
In this case, the main training goal is not to increase the individual and personal agent domain knowledge but to construct common cooperative preferences and strategies which could be synchronized with the individual preferences, knowledge, and current intervention goals of the cooperating managers.
The assumed intelligent agent model of a trainee, see Fig.7, enables deep analysis of the manager decision-making.
The supervisor may identify the causes of the trainee improper decisions. In general, they may refer either to the emergency domain or to the cooperation domain.

In the both cases thay relies on:
- insufficient or false information and, in consequence, wrong situation-assessment
- insufficient or false knowledge
- inappropriate preferences hierarchy, which includes personal motivation criteria
- temporal physical and psychical stress.

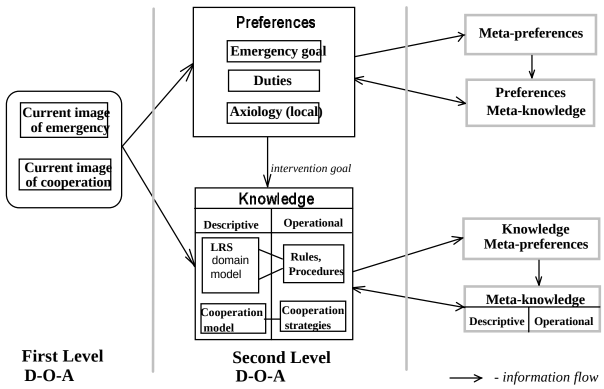

Fig. 7 The trainee model frame which may be a base for the analysis of managerial errors.

The above mentioned causes of decisional errors may be identified in different phases of the managerial reasoning, such as:
- information and expert knowledge acquisition,
- situation-assessment,
- task planning or macro decision-making, which includes:
  conflict resolution, tasks' distribution among executors, and allocation of resources.

We argued that in the preparation of the adequate heuristic rules bases should participate knowledge engineers, sociologists, and psychologists. Taking also under consideration that the cooperation training is organized for the domain specialists, we should stress that in practice, a realistic training of many emergency managers requires a tutor which is an expert in the previously mentioned fields rather than in a specific emergency management domain.

7 Conclusions

In the paper we are presented two types of the results of the MUSTER project.
The first are technological, and have direct applicative value. They are related to the constructed system.

The prototype functionalities were presented to the principal end-user involved in the Genova Multedo Oil Port emergency operations. The obtained feedback was positive, expecially in the relations with the implemented trainees user interfaces. We hope that in the near future the produced prototype will be considered as a basic environment for the development of a computerized training framework and to be used inside the major Oil Ports risk areas.
The second type of our results has rather research and development significance. They are referred to the agent-based methodology of the training and learning process that should be developed in the domain of emergency management.
An application of an abstract intelligent agent framework should enable to develop in the near future, so called, intelligent training systems as well as intelligent DSSs (Decision Support System) for management of real emergency situations. This last type of the computerized support is the subject of our paper presented on TIEMEC'95 conference [Ref.9].

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