# A COMPUTERIZED SUPPORT SYSTEM TO COOPERATIVE TRAINING IN EMERGENCY SCENARIOS MANAGEMENT AND ITS APPLICATION TO AN OIL PORT DOMAIN

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## ABSTRACT

The paper describes part of the results achieved in the framework of the MUSTER[1] project (Multi-Users System for Training and Evaluating Environmental Emergency Response). The aim of this project is to define the detailed specifications of a computer based system supporting collaborative training for emergency management. A system prototype has been implemented to support the refinement and improvement of the system specifications.

## INTRODUCTION

Collective training, a novel type of computer based training, is aimed to improve the coordination level inside multi-agents organizations and to evaluate the emergency procedures and the effectiveness of the utilized tools and devices (*Balducelli, Gadomski 93*). In fact, in the framework of situations having an high environmental risk, like ports and/or areas with an associated high energy density, the emergencies are managed by different types of authorities. Every actor, during the emergency , has his own responsabilities and defined procedures to follow but, very often, the execution is not adequate to the mutual coordination of the respective tasks.

Now it is recognized that the efficiency of an emergency management organization mainly depends on the coordination of actions among the involved decision makers.

To improve the intervention efficiency the emergency organizations execute periodically exercises on the territory: these exercises are realistic but they have a very high costs and, in addition, it is not always possible to simulate all the hypothetical accidents. An additional training method is the computer based training that exploits the simulation capability of the system. This method has a low level of realism but the costs are lower and allows to explore a wide range of situations.

For these purposes, besides to provide a real scenario specifications, the italian participants to the MUSTER project (*Andersen H.B., Andersen V. 1993*) have developed a computerized support system prototype based on an high risk area (an Oil Port in Italy) and on a true emergency event occurred some years ago (a tanker explosion in the same area). The prototype architecture consists of a network of personal workstations. In particular, the demonstrated training session is composed by a Supervisor and two trainees with their workstations.

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 scenario. In the demonstrated session one trainee represents the on-field coordinator (the coordinator agent operating near the accident, OFC), the other trainee represents the on-site coordinator (who in this case is the Oil Port director, OSC).

In the paper we will present the general requirements for the prototype, the architecture of the system and preliminary feedbacks from the end-users.

## THE COOPERATIVE WORKING FRAMEWORK

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

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

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 organisational structure, of the individual and cooperative tasks and of the intercommunication and behaviour 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 in the cooperative working structure. Based on this, the MUSTER CW model consists of two main conceptual elements:

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

Both aspects and the main information required to develop a CW model in a particular application site was outlined in a previous work (*Balducelli, Boero, Errico 1993*).

## THE SCENARIO GENERATOR

### Emergency Domain Model Definitions

The Scenario Generator utilizes a Domain model that is decomposed into three main layers:

- Layout Layer; (LL)
- Resource Layer; (RL)
- Scenario Layer; (SL)

LL includes the most static knowledge of the considered territory and are represented by more or less schematic geographical 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. For example, the port layout includes the configuration and type of piers that are constraints for ships movements. The layout is normally represented by a map, at more or less detailed level of granularity. Generally, in the proximity of accident locations, the map should be more detailed due to the increasing importance of the physical constraints in the territory, in relation with the emergency management activity. A boundary is normally present in the layout layer to divide an on-site portion of the layout from the off-site one. The on-site layout is the part of the territory under the responsability of the on-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 function 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 (*Coad and Yourdon 1990*) seems a quite natural choice. Using this perspective, the most general classes of objects were firstly defined. As in all taxonomies, the classes/objects may be specified at different levels of generality. Any attribute specified for a class at a general level is inherited by all subclasses/objects belonging to that class. Using this representation, the class *resource* is the most general class containing all the physical objects considered inside LL. A resource has the following general attributes: *goal*, *location* on layout, *vulnerabilty* level, *destructiveness* level, *degree of protection*. These types of attributes are applicable to all objects belonging to all subclasses. The contents of some of these, like goal and location on the layout does not depend on the scenario. The vulnerablity level and destructiveness level values may depends on the type of scenario. The degree of protection value may be strongly dependent about the resource location: for example the pipelines located on the pier nearest to an exploded tanker will need a strong degreee of protection to avoid the emergency propagating to other parts of the layout. Subclasses of the resources class are as follows:

*Normal Operation Resources*: these resources have the goal of supporting all the operations to be carried out inside the domain under normal circumstances. This type of resources are not directly related to emergency situations but could be involved (as *risk objects*) in the emergency or could even be a cause of an emergency situation. Resources of this type, for an oil port domain, include for instance oil-tankers, fuel loading-unloading systems, fuel containers.

*Emergency Support Resources*: these resources have the goal of supporting emergency operations. They may be equipments or human organizations and experts. In the oil port domain typical resources belonging to this class are the anti-fire local systems, anti-pollution systems, fire-brigades, tug-boat people, etc. Specific attributes associated to this type of resources are: availability time and amount.

*Resources for Services and Utilities*: these resources have the goal of supporting general services inside the layout. Electrical supply systems are one of the principal resources belonging to this class. An airport system may be another example. In general the availability of this type of resources can be of some help during the emergency situation; so a common attribute to this type of resources is availability time.
Using this type of formalization the same physical resources (human or equipment) may be instantiated with different specific attributes depending of the situation and the scenario.

### Scenario Layer

This layer contains all the 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, *accesibility* constraints to accident location, *level of storage* of hazardous materials and other particular events. In general this layer contains all the information and events which can be hardly predicted in advance and that may influence the emergency evolution.

## THE GENERAL SYSTEM ARCHITECTURE

As we can see in fig. 1, the italian MUSTER prototype configuration is composed by three workstations (one for training Supervisor and two for the trainees) connected together using Window for Workgroup system. The different tasks comunicate each other using the Network DDE (Dynamic Data Exchange) facility.

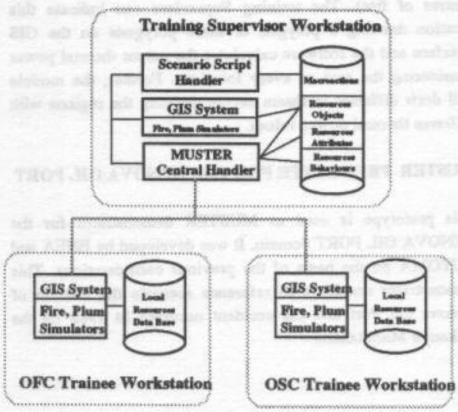


Fig. 1 - Italian MUSTER prototype configuration

### The GIS system

Every trainee and the training Supervisor utilizes a GIS system for the visualization of domain layout, resources and scenario. The trainees utilize the GIS system also to execute actions on the resource objects.

### The Muster Handler

As we said, during a training session the trainee must perform actions (using the resources layer objects) in order to avoid emergency propagation and to reduce damages to people, things etc. A trainee can also send messages to other trainees, can allocate resources etc.
Most of these actions require a certain time to be executed in reality. In fact, to move a tug-boat from a point inside the oil port to another point, the tug-boat needs some time available depending from the distance between the points and also other factors. To take in account these constraints the system utilizes a central module called MUSTER HANDLER. This HANDLER has two main tasks: the first one is to mantain the congruity of a central Database including all types of data regarding the different trainees' resources and actions; the second one is to control the response of actions requiring a certain time to be executed. When a trainee perform an action moving a resource from a point to another point (for example a tug-boat) the HANDLER calculates the necessary time to execute the action. The tug-boat will be displayed on the arrival point only after the handler internal clock will have counted the necessary time.

### The Scenario Script Handler

As mentioned above a training session involves a training Supervisor and some trainees. The Supervisor is granted all accesses to the hardware and software resources for the training program. He has the complete control of all elements of the scenery under consideration. He can manages the resources, can insert new events in the current scenario, and, if deemed advisable, he can vary the number of resources available, the conditions of their utilization, of their accessibility and availability, the operating time, the general and particular weather conditions.
The scenario script handler gives support to the training Supervisor in the task of monitoring and control the trainees' behaviour. Using the Handler the Supervisor can visualize the planned scenarios and events, the trainees expected and executed actions. He also can start/stop the training session, invke/disable the trainees' actions, visualize/start next scenarios etc.

### The Scenario Tree

The system also supports the Supervisor during the phase of session planning to generate session scripts (*Larsen et al.1995*). A session script can be conceptually viewed as a tree composed by nodes and arcs connecting different nodes as visualized in fig.2. 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.

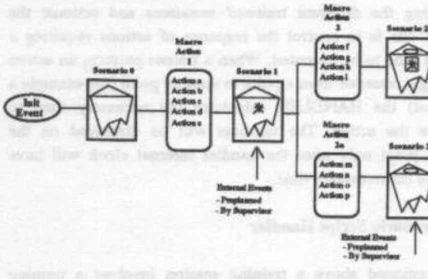


Fig. 2 - The structure of the generic Scenario Tree

In the actual prototype the planning phase will not be demonstrated. So the prototype will have an already designed script that corresponds to the Hakouyu Maru accident (*Casablanca and Meta 1982*) history with some alternatives (different arcs at some nodes) in a set of defined point inside the history itself.

### Macroactions

As described above, a *macro action* is the set of all elementary expected actions generating a new scenario from the old one. To explain more deeply this concept it is necessary to give a more detailed definition of an action. An action may be described at different levels of accuracy: in fact we can say that during the emergency the on-field coordinator performs the action to allocate the Fire Brigades motortanks near the fire locations, without establishing the precise locations for every motortank or the exact number of motortanks: these are in fact more specific information associated to the generic action of motortanks allocation.

To face the fire, the agent must surely execute the more generic part of the action (allocating motortanks) but he can execute the more specific part of the action in many ways and the action results may be acceptable or not respect to an higher or lower degree of evaluation. During the execution phase the system *controls* only the generic part of the action, the specific part is only *monitored* on the training Supervisor screen.

The control and the evaluation of the specific part is done by the Training Supervisor itself.

### Events

In the passage from an old scenario to a new one may be also involved external physical events like fires, explosions ect.. The events can be predetermined in the planning phase by the training supervisor or inserted on line during the execution phase. Evolutions of the physical events may be also illustrated with the support of external simulators.

### The External Simulators

The MUSTER system utilizes also external simulators to furnish data about the effects of the accident releases. In the Italian Muster prototype simulators of fires (calculating the air temperature distributions) and of smoke column dispersion was implemented. To calculate the fire's power the simulator needs the fire location (or the fire locations if there are more centres of fire). The training Supervisor can indicate this location drawing a polygon or more polygons on the GIS interface and the software calculates the output thermal power considering the area of every locations. Further, the module will draw different isotherm curves dividing the regions with different thermal power values.

## MUSTER PROTOTYPE FOR THE GENOVA OIL PORT

This prototype is used as 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 on the Hakouyu Maru tanker.

**The formalization of the selected accident**

In fig. 3 we can see the formalization of the scenario tree used for the Italian MUSTER prototype training session.
As it is evidenced from the figure there is a right path of the accident evolutions and some wrong paths. Wrong paths may be initiated from wrong trainees' decisions at some critical points: for instance in the Macro Action 3 there is the Port Evacuation action. Really this was a very important action.

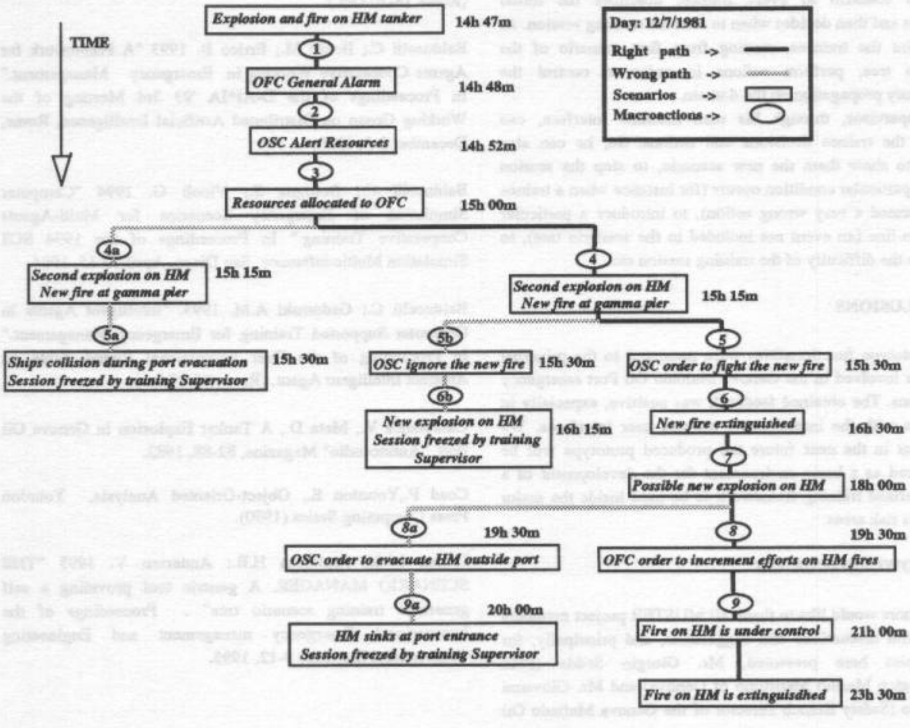


Fig. 3 - The Hakouyu Maru accident scenario Tree

Together with this action the responsible trainee (the Oil Port Director) must indicate the right order of the ships evacuation. If this order is wrong the possibility of ships collisions arises and the training session will be stopped (freezed by Supervisor) as indicated in the scenario tree after the Macro action 5A.

**Involved Trainees**

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 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 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 begin 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, can 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.

## CONCLUSIONS

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 relations with the implemented trainees user interfaces. We hope that in the next future the produced prototype will be considered as a basic environment for the development of a computerized training framework to be used inside the major Oil Ports risk areas.

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