# DESIGNING A SOFTWARE TOOL TO PLAN FIGHT ACTIONS AGAINST MARINE POLLUTIONS

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**ABSTRACT**
The purpose of the paper is to present the design of a software tool to plan fight actions against marine pollutions. In particular such tool has to assist crisis management staff to minimise pollution impact due to maritime accident. From a methodological point of view, the paper shows the importance of developing ontologies (i) for structuring a domain (at a conceptual level) as its actors perceive it and (ii) for building computer tool for aid solving problems in that domain.

Keywords: ontology, decision support system, marine pollution, crisis management

## 1. INTRODUCTION

Although the Mediterranean is only one hundredth of the sea surface it supports thirty percent of the volume of international maritime traffic (2200 ships are sailing continuously): either through exchanges between the 305 ports scattered along its coasts, or the use of its transit routes. An estimated 50% of goods transported could present a risk to different degrees.

A study on shipping accidents in the Mediterranean sea (REMPEC 2002), conducted between 1977 and 2003 identified 376 accidents involving hydrocarbons and 94 accidents involving hazardous and noxious substances (HNS). These accidents have resulted in a total discharge of 305,000 tons of hydrocarbons and 136,000 tonnes of HNS. These events highlight the criticality of the risk induced by transport activities in that region.

Marine pollution has always had a strong impact on coastal populations. Coastal water polluted leads inexorably to a disruption of ecosystems and significant risks to people. The economic losses to the affected area are often important because of damage suffered by the tourism, fisheries and aquaculture.

In general, the strategy of fight against marine pollution from hydrocarbon following shipping accident is divided in two complementary stages: (i) recovery of the maximum volume of hydrocarbon on the sea surface and when the pollutant reached the coast (ii) cleaning the polluted coastline. There are many intervention techniques to combat pollution and their effectiveness depends on the situations in which they are implemented. Thus, it appears that the choice of a fight technique in a response plan is not trivial and requires taking into account a large number of parameters.

The project CLARA 2 (Calculations Relating to Accidental Releases in the Mediterranean) brings responses to these problems. It aims to develop and implement a computer tool to assist management crisis resulting from a maritime accident having caused a spill of pollutants. To carry out this national project (funded by the Research National Agency), a consortium of 13 partners was formed (CLARA 2 Consortium 2006). The purpose of this paper is to focus on the elaboration process of the GENEPI module (GENEration de Plan d'Interventions) from CLARA 2, which aims to plan fight actions against marine pollutions.

The current work lies in the following research fields: (1) from the maritime field perspective, the paper presents a software tool to assist crisis management staff to minimise pollution impact and (2) from a methodological perspective, the paper shows the importance of developing ontologies (i) for structuring a domain (at a conceptual level) as its actors perceive it and (ii) for using these ontologies to build computer tools for aid solving problems in that domain.

An overview of the CLARA 2 project is presented in section 2 and section 3 presents the functioning principles of the GENEPI module. Section 4 describes the methodological approach and the process used to build the GENEPI module. In the section 5 the implementation of the process is developed and exemplified. Section 6 presents the architecture of the GENEPI module. Section 7 presents the conclusions.

## 2. THE CLARA 2 PROJECT

The CLARA 2 project aims to provide a tool for managing crises induced by marine pollution, whether of chemical or petroleum. This tool should facilitate the rapid establishment of relevant exclusion zones to alert, but also to protect people, goods and environment, to mobilize appropriated fighting means and to anticipate critical situations. It also provides information on the capabilities of bio-accumulate in the food chain substances released and a preliminary approach to risk in terms of toxicological effects on humans is proposed in case of atmospheric dispersion of toxic gases.

The software tool (Figure 1) is based on a simulator designed to predict the location of a pollutant (Hydrodynamics Module / Meteorological data Module), and changes in its concentration in the sea (Product behaviour Module) and in the atmosphere (Atmospheric Dispersion Module) following a massive spill. It helps to know the distance effect in the case of a fire (Fire Module), provides information on the bioaccumulation capacity of some marine organisms (Module Impact Assessment) and provides sensitivity indicators according to the polluted areas (Vulnerability Maps). In addition, CLARA 2 generates plans on the steps to take and methods of intervention to implement (the generation module of intervention plans: GENEPI). The relevance of results provided by the different models is based on the relevance of the database (Product Physical-Chemical Database) of physico-chemical and eco-toxicological substances, which are the most representative (in terms of tonnage and frequency) of the Mediterranean maritime transport.

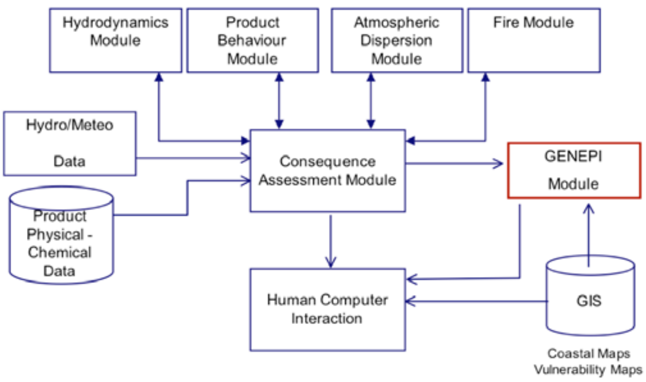


Figure 1: architecture of the CLARA 2 software tool

## 3. THE GENEPI MODULE

The fighting plans generated by GENEPI take account of the accidental situations and their changes over time. The set of methods and intervention techniques that could be mobilized have been classified and suitability criteria with situations have been established and associated to each of them. Figure 2 shows the functioning principle of this module.

Access to the GENEPI module is done through an observation vector of a real situation (Vreel_sit) and / or an observation vector of a simulated situation (Vsim_sit) resulting from another CLARA 2 Modules. Based on this observation vector and the suitability criteria associated with each fight (intervention) action, the selection system (Selection of Intervention Actions) accesses to the Action Classification to extract the most relevant ones. The selection is based on the analysis of suitability criteria associated with each intervention technique. The result is a set of fight action called "candidates actions". It will serve as the basis for generating fight Plans. Each Plan can be simulated to be validated. Its users can operate this module automatically or in a coordinated and controlled way.

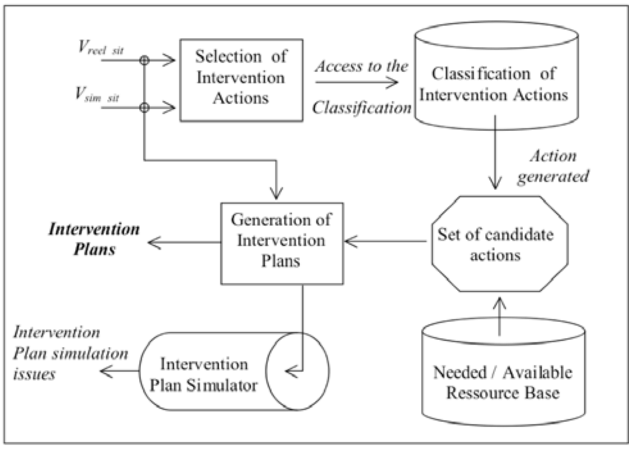


Figure 2: Functioning principle of the GENEPI Module

## 4. METHODOLOGICAL APPROACH

### 4.1. Analysis of the problem

One of the main problems arising during the conception of new computing tools to assist the resolution of safety problems is linked to the stability of the terminology. This problem is symptomatic of semantic and conceptual distances within actors of the community for which computing tools are intended. These distances can emerge within critical situations and lead to accidents or to increase accident consequences. The notion of ontology and works currently developed by the scientific community of the knowledge engineers can bring interesting answers to this problem. One of the objectives of ontology is to facilitate the exchanges of knowledge between human beings, between human beings and machines as well as between human beings through machines (Uschold and Grüninger 1996).

The advantages in developing ontologies to solve problems arising in the field of safety and risk management are the following: (i) they structure a domain in highlighting concepts and semantic relations that are linking these concepts and, (ii) they can be used to be the base for new computer tool design. Tools so built are carrying knowledge shared by the actors of the domain, what makes them more effective within critical or crisis situations.

The followed methodological process is based on the "Knowledge Oriented Design" (KOD) method (Vogel 1988) (Mercantini 2007). KOD belongs to the family of methods coming from Cognitive Engineering and designed to guide the engineer (or the knowledge engineer) in its task of developing knowledge based systems. This method was designed to introduce an explicit model between the formulation of the problem in natural language and its representation in the formal language chosen. The inductive process of KOD is based on the analysis of a corpus of documents, speeches and comments from expert domain, in such a way to express an explicit cognitive model (also called conceptual model).

### 4.2. The KOD method

KOD is based on an inductive approach, which requires to explicitly express the cognitive model (also known as the conceptual model) based on a corpus of documents, comments and experts' statements.

The main features of this method are based on linguistics and anthropological principles. Its linguistics basis makes it well suited for the acquisition of knowledge expressed in natural language. Thus, it proposes a methodological framework to guide the collection of terms and to organize them based on a terminological analysis (linguistic capacity). Through its anthropological basis, KOD provides a methodological framework, facilitating the semantic analysis of the terminology used to produce a cognitive model (conceptualisation capacity). It guides the work of the knowledge engineer from the extraction of knowledge to the development of the conceptual model.

The employment of the KOD method is based on the conception of three types of successive models: the practical models, the cognitive model and the software model, as represented in Table 1. Each of these models is conceived according to the paradigms: <Representation, Action, Interpretation>. The Representation paradigm allows to model the universe such as an expert represents it. This universe is made of related concrete or abstract objects. The Action paradigm allows modelling the behaviour of active objects that activate procedures upon the receipt of messages. In consequence, action plans devised by human operators as well as by artificial operators will be modelled in the same format. The Interpretation / Intention paradigm allows modelling the reasoning employed by the experts in order to interpret situations and to elaborate action plans related to their intentions (reasoning capacity).

The practical model (PMi) is the representation of a speech or a document of the corpus, expressed in the terms of the domain by means of taxemes (static representation of objects), actemes (object activity representation) and inferences (at the basis of the task cognitive structure). The cognitive model is built by abstracting the practical models. It is composed of taxonomies, actinomies and reasoning patterns. The software model result from the formalization of a cognitive model expressed in a formal language, and is independent of programming languages.

Table 1. KOD, the three modelling levels.

| **Paradigms / Models** | **Representation** | **Action** | **Interpretation** |
|---|---|---|---|
| **Practical** | Taxeme | Acteme | Inferences |
| **Cognitive** | Taxonomy | Actinomy | Reasoning Pattern |
| **Software** | Classes | Methods | Rules |

### 4.3. The ontology building process using KOD

Research work in Ontology Engineering has put in evidence five main steps for building ontologies (Gandon, 2002)(Aussenac-Gilles and al. 2000) (Dahlgren 1995)(Uschold 1996; Uschold *et al*. 1995) (Fernández-López 1999; Fernández and al. 1997):

1. *Ontology Specification*. The purpose of this step is to provide a description of the problem as well as the method to solve it. This step allows one to describe the objectives, scope and granularity size of the anticipated ontology.
2. *Corpus Definition*. The purpose is to select among the available information sources those that will allow the objectives of the study to be attained.
3. *Linguistic Study of the Corpus*. This step consists in a terminological analysis of the corpus in order to extract the candidate terms and their relations. Linguistics is specially concerned to the extent that available data for ontology building are often expressed as linguistic expressions. The characterization of the sense of these linguistic expressions leads to determine contextual meanings.
4. *Conceptualization*. Within this step, the candidate terms and their relations resulting from the linguistic study are analyzed. The candidate terms are transformed into concepts and their lexical relations are transformed in semantic relations. The result of this step is a conceptual model.
5. *Formalization*. The purpose of this step is to express the conceptual model with a formal language.

The projection of the KOD method on the general approach for developing ontology shows that KOD guides the corpus constitution and provides the tools to meet the operational steps 3 (linguistic study) and 4 (conceptualization).

Under previous researches, the KOD method has been already implemented (Mercantini et al., 2003; 2004; 2007) in the domains of road safety, safety of urban industrial sites and study of conduct errors of industrial plants.

Table 2. Integration of the KOD method into the elaboration process of ontology

| Elaboration process of Ontology | KOD process | Elaboration process of ontology with KOD |
|---|---|---|
| 1. Specification | | 1. Specification |
| 2. Corpus definition | | 2. Corpus definition |
| 3. Linguistic study | 1. Practical Model | 3. Practical Model |
| 4. Conceptualisation | 2. Cognitive Model | 4. Cognitive Model |
| 5. Formalisation | | 5. Formalisation |
| | 3. Software Model | 6. Software Model |

## 5. ELABORATION OF THE ONTOLOGY

### 5.1. Corpus Definition

This phase's objectives are to identify, within the problem domain, the relevant knowledge for the GENEPI module. It requires a well-defined and well-delimited problem domain.

In our study, two important phenomena that define the field and the problem to be addressed are: (i) maritime accidents and (ii) interventions to contain the consequences of the accident. Thus, the corpus has been established on the basis of documents from CEDRE (le Centre de Documentation, de Recherche et d'Experimentation sur les pollutions accidentelles des eaux) and REMPEC (the REgional Marine Pollution Emergency Response Centre for the Mediterranean Sea) in respect of accidents that have already occurred as well as the implementation of emergency plans. The types of documents that make up this corpus are the following:

- Documents relating to the evaluation of each fight technique or method,
- General documents about the organization of emergency plans (plan ORSEC, « Organisation de la Réponse de SEcurité Civile", Organization of Civil Security Response),
- Return on experience documents about the major maritime disasters such as that of the Erika, Prestige, etc..
- Return on experience documents about maritime accidents of lower magnitudes.

### 5.2. Practical models

This phase consists in extracting from each document belonging to the corpus, all the elements (objects, actions, and inferences) that are relevant to accident representation and fight action implementation.

#### 5.2.1. Extracting taxems

To obtain taxems, the linguistic analysis is performed in two steps: the verbalization and the modelling into taxems. The verbalization step consists in paraphrasing the corpus documents in order to obtain simple phrases, which allow qualification of the terms employed during document analysis. Thus, some terms appear as objects, others appear as properties, and yet others appear as relations between objects and values. The modelling step consists of representing the phrases in the format of taxem: <object, attribute, value>.

The taxem characterizes an object from the real world by means of a relation (attribute), which links the object to a value. There are five types of relations: classifying (is-a, type-of), identifying (is), descriptive (position, failure mode, error mode, cause…), structural (composed-of) and situational (is-in, is-below, …).

The example that follows illustrates the process employed to obtain the taxems from one phrase extracted from the "Prestige" accident.

"... On November 13$^{th}$, 2002, the Prestige oil tanker flying the Bahamian flag, sends an emergency message from the Finisterre Cape ..."

*Paraphrases*

1. The Prestige is a oil tanker
2. The Prestige flies the flag of the Bahamas
3. On November 13, The Prestige is located at the Finisterre Cape
4. On November 13, the Prestige sends an emergency message

*Taxems*

1. <Prestige, IS A, oil tanker>
2. <Prestige, FLAG, Bahamas>
3. <Prestige, LOCATION, Finisterre Cape>
4. <Prestige, DATE, November 13$^{th}$>

The last paraphrase is related to an action, so it will be modelled by means of an actem. The extent of this analysis at the Corpus, have allowed obtaining the set of taxems needed for the representation of the universe described by the corpus of documents. An object of the real world is modelled by the sum of related taxems extracted from the set of documents of the corpus.

#### 5.2.2. Extracting actems

In order to obtain the actems, the linguistic analysis consists on identifying verbs that represent activities performed by actors during marine pollution or object behaviour. In general terms, an activity is performed by an action manager, by means of one or more instruments, in order to modify the state (physical or knowledge) of the addressee. The action manager temporarily takes control of the addressee by means of instruments. Occasionally the action manager can be the one who directs the activity and at the same time is also subjected to the change of state (example: knowledge acquisition). The following example illustrates how to extract actems from the Corpus.

"... the Prestige sends an emergency message..."

The activity is "SENDING an emergency message". Once identified, the activity is translated into a 7-tuple (the actem):

<Action Manager, Action, Addressee, Properties, State1, State2, Instruments>,

Where: the Action Manager performs the action; the Action causes the change; the Addressee undergoes the action; the Properties represent the way the action is performed; State 1 is the state of the addressee before the change; State 2 is the state of the addressee after the change; Instruments, is one or a set of instruments representing the means used to cause the change.

The actem "SENDING an emergency message" is, thus, represented as following:

*<Prestige Commandant, SENDING an emergency message, CROSS MED, (date, location, duration), CROSS MED (do not know), CROSS MED (know), Radio>.*

Where CROSS MED means "Centre Régional Opérationnel de Secours et de Sauvetage en Méditerranée », which is the French organism that receives any emergency messages from ships in difficulties. Figure 3 illustrates this actem and figure 4 illustrates the case of a fight action where it has been necessary to extend the actem formalism to take in account suitability criteria:

*<Action Manager, Action, Addressee, Properties, Suitability Criteria, State1, State2, Instruments>*

Actems model the task activity. It is composed of textual items extracted from the reports, which describe the state change of an object as described by the domain experts. Each element of the 7-tuple (or 8-tuple for fight actions) must be previously defined as a taxem.

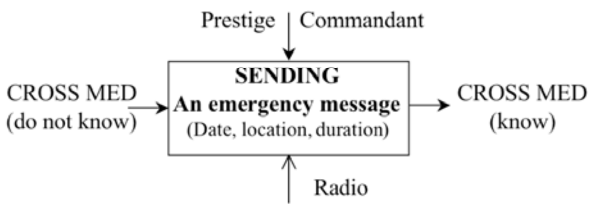


Figure 3: Representation of the Actem "SENDING An emergency message".

| FLUSHING | |
|---|---|
| **Components** | **Values** |
| **Action Manager**<br>Operator | {Human Means} |
| **Addressee**<br>Substratum | {Sand, Stone, Concrete, Rock, etc.} |
| **Addressee State1**<br>State | {Polluted, Cleaned} |
| **Addressee State2**<br>State | {Polluted, Cleaned} |
| **Instruments** | {Pump + Water Hose + Recovery Means} |
| **Properties** | Efficiency |
| **Suitability Criteria** | Site_Acces, Viscisity_Pollutant, Pollution_level, Kind_Of_Substratum, etc. |

Figure 4: Representation of the Actem "FLUSHING" in a table form.

## 5.3. The cognitive model

This phase consists on the analysis and abstraction of all the Practical Models built in the previous phase. The objective is to build the domain ontology. In other words, the aim is to classify the used terminology and thus obtain the KOD Cognitive Model

### 5.3.1. Building the Taxonomies.

*Term Analysis:* the analysis consists in solving problems induced by homonym and synonym terms, with the objective to build a common terminology.

*Concept Identification:* This step is based on the analysis of the taxems and consists in highlighting the nature of the attributes, which characterize each object. The attribute nature is the basis for the construction of the taxonomies (relations 'kind-of' and 'is-a') or other tree type structures (relations: 'is-composed-of', 'position', 'is-in', 'is-below', 'is-above', etc.).

As an example, from the analysis of the set of taxems it was found that the term "Skimmer" is meaningful and thus it deserves the status of a concept. It is significant of a set of recovery devices (modelled by means of taxems). As a result of the analysis of the terms related to "Skimmer", the taxonomy of the figure 5 has been built and the "Skimmer" concept is defined through his attributes as follow:

**The Skimmer Concept**

<Type, Flow, Quantity, Storage Location, City, Dimension, Weight, Performance Limit, Selectivity, Recovery Rate>

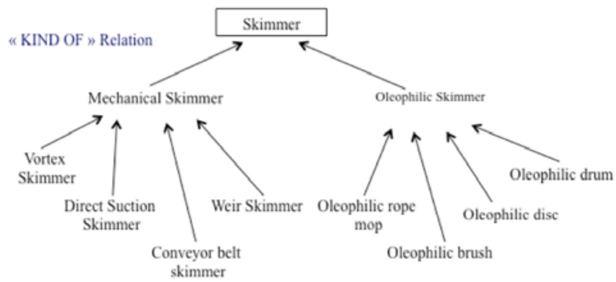


Figure 5: The Skimmer taxonomy

All the taxems of the corpus are organized in taxonomies and each concept has been defined as shown in the example.

### 5.3.2. Actems abstraction

One result of the actem analysis is that actems can be devided into five main action categories:

- Actions related to pollutant behaviour,
- Actions related to accidented ship behaviour,
- Actions related to reasoning patterns,
- Actions related to CLARA 2 services.
- Actions related to operations against pollution,

Amongst actions related to pollutant behaviour we can cite: Evaporation, Dissolution, Drift, Emulsion.

Amongst actions related to accidented ship behaviour, we can cite: Listing to starboard, Sinking, Sending an emergency message, Requesting evacuation.

The actions related to reasoning patterns such as « Choosing the shoreline clean-up methods » are used to select or to plan fight actions. To be performed, they use the suitability criteria associated to each actem.

The actions that belong to the CLARA 2 services category are implemented to improve the GENEPI functionalities. As examples we can cite: Coastal Mapping, Evaluating the Pollution Movement, Evaluating the Pollution Impact.

The actions of the last category are fight actions. They are divided into two main classes: (i) the shoreline clean-up methods and (ii) the clean-up methods on the sea. The set of actems from this category has been structured by means of a Taxonomy. Figure 6 is an extract of this taxonomy.

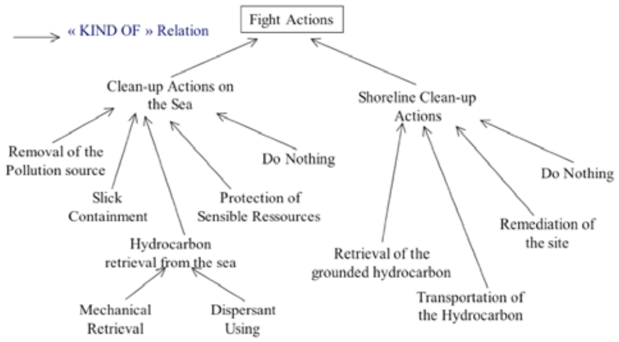


Figure 6: Extract of the Fight Action Taxonomy

Some actems of this category can be organized in a structural and temporal way to form actinomies. The interest of this kind of structure is that actions are already planned.

# 6. ARCHITECTURE OF THE GENEPI MODULE

The architecture of the GENEPI module (Figure 7) has been designed around the ontology enriched with the instances of the concrete classes. The association of the ontology with instances constitutes a knowledge base (Maedche 2002).

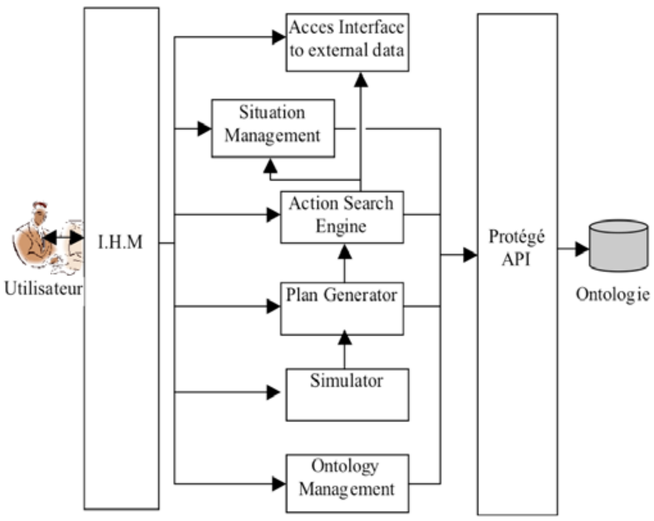


Figure 7: Architecture of the GENEPI module

## 6.1. The notion of Situation

The analysis of accident stories from the corpus, shows that each accident has its own characteristics and that for a particular accident, the circumstances and context change from one moment to another. To take this into consideration, we defined the notion of Situation. A Situation consists of a set of attributes ($S$) that characterizes the accident and its context. The set of these attributes is a superset of the set of suitability criteria ($Ca$) associated to fight actions. Thus, attributes common to $Ca$ and $S$ have the same types.

Instances of the Situation are obtained from data delivered by the access interface to external data (coming from others CLARA2 modules), and from data supplied by the user.

## 6.2. The Action Search Engine

The search engine receives as input the Situation and the Domain in which searching the fight actions in the ontology. The domain is identified by the name of the class that characterizes it into the taxonomy of the fight actions (Shoreline Clean-up Actions, Mechanical Retrieval, etc.). As results, it provides four sets of fight actions:

- The set A, which contains the actions where all criteria are verified,
- The set B, which contains the actions where at least one of the criteria could not be assessed by lack of information in the situation,
- The set C, which contains the shares of which at least one criterion was not satisfied,
- The set D, which contains the actions of the set B enriched by criteria not assessed.

### 6.2.1. The selection rules of actions

The rules for selection of fight actions are based on the suitability criteria and the values taken by the corresponding attributes of the situation.
The rules are of the form:

$$c1 \wedge c2 \wedge ... \wedge cn \rightarrow True / False$$

With c1, c2, ... cn, the criteria associated to a fight action. The conclusion of the rule is about the possibility whether or not to select the action. A criterion is satisfied if the value taken by the corresponding attribute of the situation is compatible the criterion constraints.

### 6.2.2. The algorithm for selecting actions

Upon the receipt of the Situation, the algorithm analyzes the actems involved in the Search Domain. From each ACTEM, it extracts the criteria and it applies the selection rules previously presented. According to the results obtained, the actem is placed in the corresponding set (A, B, C or D).

After running the algorithm, if the user is not satisfied with the result, it can enrich the situation to assess the criteria that have not been. This new running should reduce the size of the B set, putting the actions which were either in the set A or in the set C.
The algorithm is independent of changes in the ontology.

## 6.3. The ontology management module

This module provides users with the functions needed for maintenance (updating, adding and deleting classes, attributes and instances) and consultation (searching knowledge) of the ontology.

# 7. CONCLUSION

The paper presents the first results about the design of a software tool (the GENEPI module) to plan fight actions against marine pollution. The GENEPI module is a part of a wider research program: CLARA 2.

The methodological process to build GENEPI is based on the elaboration of an ontology. The purpose of that ontology is to structure the domain (maritime accidents) according to the problem to solve (to plan fight actions) and to the problem solving method.

The ontology was obtained through a cognitive approach, which consisted in applying the KOD method, which has proven to be adequate.

The Situation Management module, the Ontology Management module and the Action Search Engine are in service. The Plan Generator module and the Simulator are currently in progress.

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