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Interoperability of Information Systems in Crisis Management: Crisis Modeling and Metamodeling

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Abstract. In a crisis situation (natural disaster, industrial accident, etc.) several partners have to act simultaneously to solve the emergency situation. Their coordination in such a context is a crucial point, especially in the first moments of the crisis. Their interoperability (precisely their Information Systems interoperability) is a major component of the success of the network. *ISyCri*¹⁷ French project propose to tackle this topic according to two aspects: (i) *responsiveness* of the network (its ability to act rapidly and efficiently) and (ii) *flexibility* of the obtained system of systems (its ability to evolve and follow the changing situation). This is so an *agility* problem of ISs of partners. This article presents the first results of this work: a metamodel of crisis situation and its ontological links with collaborative process design, and also the treatment of a first case of study, a *NRBC*¹⁸ exercise.

Keywords: ontology, crisis management, interoperability, information system, collaborative process, system of systems, SOA, MDA.

1 Introduction

On a crisis situation, different actors have to act (generally) simultaneously in a hurry to reach the shared goal of crisis reduction. These actors are heterogeneous by nature (mission, equipment, culture, etc.). To be efficient, they have to collaborate, or at least to coordinate their actions, in order to build a coherent

¹⁷ Interoperability of System in Crisis situation.

¹⁸ Nuclear Radiological Bacteriologic Chemical.

response. However each performer remains autonomous for the deployment of its means and the achievement of its own objectives (even if a general entity is often in charge of the global authority).

Generally, each actor owns its own information system (IS) adapted to its own needs, resources and processes. That is why, we believe, as shown in [1], that the major issue of integration of partners in crisis context is the ability of these information systems to communicate, to exchange information, to share services and to coordinate their behaviors according to the global goal of crisis reduction. This observation is, for the authors, the keystone of the efficiency of crisis reduction.

The point of the *ISyCri* project is to provide partner organizations involved in such a situation with a *Mediation Information Systems* (MIS) able to merge their respective heterogeneous and autonomous ISs into a global *System of Systems* (SoS).

This MIS, as the linking support between ISs have to meet the two mains requirements: (i) providing a fast and efficient link between ISs (in order to ensure *responsiveness*) and (ii) following the unavoidable evolutions of the crisis by remaining adapted and rightly dedicated to the specific needs of the crisis situation and to the – possibly changing – group of involved partners working on its resolution (in order to ensure *flexibility*). Thus the MIS design should deliver an *agile* result (*agile* can be seen as the union of *responsiveness* and *flexibility*). The global principle of the *ISyCri* project and its contents will be presented in the first section of this article. We will then focus on the crisis modeling part, as a way to build the first step to MIS design.

In order to meet its objectives, the *ISyCri* project plans to set up a global crisis metamodel. This metamodel can be seen as the combination of two ontologies: one for crisis characterization and one for reaction processes. The knowledge supplies by the instantiation of this metamodel can be used, first to model the adequate MIS to react promptly to the situation and second to maintain the model of the crisis in order to follow its evolution. The proposed metamodel and the ontological objectives will be shown in the second part of this paper.

Thirdly, the authors will present the instantiation phase of the metamodel on the treatment of a particular instance: a civilian training exercise concerning a NRBC context. This third part will show the adequacy of the proposed metamodel and the choices the authors made to create the dedicated crisis model. This is a way to test the metamodel and also a capitalization phase offering formalized knowledge on crisis situations for the continuation of the project.

ISyCri is a project supported by the French Research Agency (*ANR* for *Agence Nationale de la Recherche*¹⁹) involving five main partners: two companies (*THALES-Communication* and *EBM-WebSourcing*) and three academic labs (*DR/GI* from *Ecole des Mines d'Albi-Carmaux*, *IRIT* from *Université de Toulouse I* and *LGI2P* from *Ecole des Mines d'Alès*). Institutional partners are also providing their user point of view. This project will stand from the end of May 2007 to the beginning of June 2009.

¹⁹ French national agency for research.

2 Overview of the *ISyCri* Project

The authors believe that *integration* of partners is a crucial step on the way of success in crisis reduction. The authors point is to propose to solve this issue of integration of partners by the means of *ISs interoperability*. According to *InterOp*²⁰, Interoperability is “the ability of a system or a product to work with other systems or products without special effort from the customer or user” [2]. For the authors, *Interoperability* can be seen as the *collaborative maturity level* (of organizations) adapted to *integration*, which can be seen as the ultimate *collaboration level* (of network).

2.1 A Method of Mediation Information System Design

Ensuring partners’ ISs interoperability is not a trivial issue. The authors believe it is rational to tackle this topic on the base of existing partners’ ISs. Another approach could propose to rebuild partners’ ISs, but the authors believe such a radical approach can not be considered as a realistic one. The goal of *ISyCri* is thus to provide a method of MIS design. The two crucial needs of *responsiveness* and *flexibility* (i.e. *agility*) must be covered. Due to the nature of the MIS (an information system), we propose to develop our design approach on the MDA²¹ precepts. The general view of this design method is shown on next figure (using the “Y” of the MDA approach):

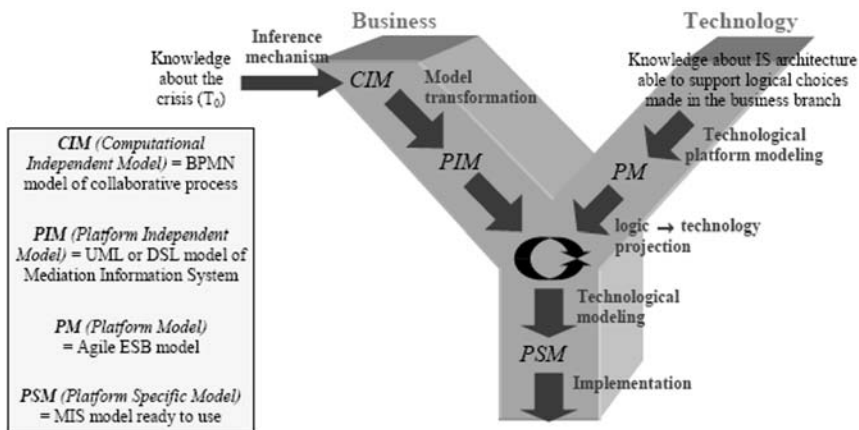


Fig. 1. Proposed MIS Design method in the MDA context (an overview).

Knowledge about the crisis context allow to model the specific situation according to the crisis metamodel and the corresponding ontology. Using this characterization, the crisis ontology provides a deduced model of an adapted collaborative process: the *CIM* (which could be enriched and validated). This step

²⁰ InterOp is a European Network of Excellence (NoE) dedicated to Interoperability issues.

²¹ Model-Driven Architecture.

is based on the adaptation of the results about the deduction of collaborative process model (in industrial context) from collaboration characterization (using ontology) presented in [3] and [4]. A model transformation mechanism use this *CIM* to build (in UML²² or in a specific DSL²³) the logical view of the MIS: the *PIM*. This mechanism is directly inherited from [5] and propose a SOA²⁴ structure for the MIS. Concurrently, the ESB²⁵ targeted technologic platform is modeled: the *PM*. ESB technology has been chosen because of its obvious adequacy with SOA principles. Some partners of the *ISyCri* project are skilled in these technologies. Next, a projection (logic to technology) provides a MIS computable model: the *PSM*. This design method and ensure the exigency of *responsiveness* listed below, but concerning the requirement of *flexibility* a complementary study should be added (such as loops in the method).

2.2 Contents of the *ISyCri* Project

Obtaining such a MIS design framework implies to divide the whole *ISyCri* project into several tasks which provide the needed elements to support the MIS design method itself. Those tasks can be listed as follow:

2. *Ontology building*: This first task will be developed in section 3. however to summarize, the authors aim at building a *global crisis ontology* providing a way to deduce adequate collaborative processes from crisis descriptions. This *global crisis ontology* is built by linking semantically two ontologies which are *crisis ontology* and *response ontology*. *Crisis* is organized in two parts: the *studied system* (including people, natural site, goods, etc.) and the *crisis characterization* (containing elements of crisis identification, such as type, gravity, trigger, etc.). *Response ontology* represents the *treatment system* deployed to reduce the crisis as well as the *collaborative process* executed.
6. *Logical modeling of MIS*: Extracting the embedded knowledge from collaborative process(es) model (*CIM*) in order to design the logical model (*PIM*) can be seen as a model transformation task. We already have some results on this field (in industrial collaboration situations) which can easily be extended in crisis context. This work is especially focused on SOA approach.
7. *Technical Modeling of architecture and projection from logical view to technological view*: We believe ESB can be a pertinent candidate for an adequate technological platform. It is essential to study and to model the structure of such a tool in order to provide the *PM*. Furthermore, mechanisms of projection of logical view (*PIM*) onto this technical view (*PM*) should also be established.

²² Unified Modeling Language.

²³ Domain Specific Language.

²⁴ Service-Oriented Architecture, a logic approach for IS conception based on clustering functions.

²⁵ Enterprise Service Bus, a technological solution for service-based IS.

8. *Study of the dynamic part*: The keystone of the added-value of the *ISyCri* project is the ability of the MIS to follow changes of the crisis situation. This capacity can be carried by several levels: the process engine could be flexible enough to support evolutions of the dynamical model of the network. This is flexibility at the *implementation level*. In mind of the authors it is possible to bring flexibility at any *MDA levels* (PSM, Projection, PIM, CIM). An iterative approach can be used to bring a “loop” in the design process (on precise looping criteria). This study remains obviously a critical task of the *ISyCri* project.
9. *Experimentation*: Such a task is a generic part of this kind of project. It will be based on specific use-cases in order to check the described principles.

3 Crisis Characterization and Collaborative Process Deduction

This section will present the theoretical aspects of collaborative process inference. The main principle is to use a crisis ontology (including descriptive part and dynamic part, which is the response process) in order to formalize the knowledge available at the moment (about the crisis situation). The result is a partial instantiation of the crisis ontology. The incomplete part (especially the dynamic view) have to be inferred from the existing knowledge using deduction mechanisms and connection rules specific to the generic crisis ontology. The point is to obtain a proposal of a collaborative process adapted and dedicated (by construction) to the specific crisis situation which have been characterized through the ontology.

The obtained process could obviously need to be validated and/or completed by experts (crisis expert or member of the collaborative network) in order to become a pertinent dynamic suggestion.

3.1 Ontological Principle

The following picture (Fig. 2) presents the global structure of the crisis ontology the authors aim to use. Its design will be based on a crisis metamodel (in UML) presented in part 3.2.

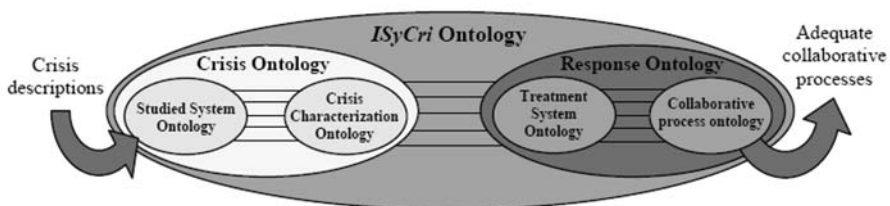


Fig. 2. Ontological architecture of the deducing mechanism (sub-ontologies and links).

ISyCri Ontology contains two main parts (*crisis ontology* and *response ontology*) which contains each one two sub-parts (*studied system* and *crisis characterization* for the *crisis ontology* and *treatment system* and *process* for the *response ontology*). These sub-ontologies of *ISyCri* ontology are connected with each others using semantic links or structural links inherited from the metamodel (links connect elements of *ISyCri* ontology, for instance, a *start event* is connected to a *crisis* through a *trigger* link).

Once defined, such a metamodel covers the whole crisis representation but it cannot express the dynamic of such situations. We need to make it more expressive and absolutely non-ambiguous to have its instances able to provide the dedicated collaborative processes. One possible approach to meet this requirement is to use descriptive logic-based ontologies. We used the approach and definition given by Thomas Gruber [6] to get an ontology which has to be specified as clearly as possible, all concepts being possibly defined axiomatically. So, the main constraints under the building of the ontology are to use only explicit assumptions, excluding any implicit behavior of the system in order to provide a full and clean model usable by the inferential services we planned to use. Technically speaking, our UML metamodel was translated into an OWL-DL ontology. In comparison with OWL-Full or OWL-Lite (subsets of the same language), OWL-DL offers large expressivity possibilities and is the only one which ensures computational completeness and decidability: it is fully usable by computers program.

3.2 Crisis Metamodeling

This part presents the *crisis metamodel* the authors point to use in order to build the *ISyCri* ontology presented previously. This metamodel has been built on the basis of the capitalized knowledge about several studied crisis (especially civil and humanitarian crisis) and about risk management [7]. We choose UML language to design this metamodel. This is the first stabilized version.

The way of building the ontology from the UML metal-model derives from [8]. By this way, we ensure not to lose any information nor relation from the UML description. The structures of the ontologies are based on the UML metamodel where each UML class becomes an OWL class. In the same way, UML relationships between classes are OWL properties. The original metamodel was split into two separate parts. The first one describes crisis while the second one is focused on the resolution process. This approach eases the maintenance of the whole system, allowing the replacement of the resolution process ontology.

The proposed metamodel may be cut in three main parts (which cover the four parts of the *ISyCri* ontology presented in Fig. 2 of part 3.1.): the *studied system* (corresponding to the studied system ontology), the *crisis characterization* (corresponding to the crisis characterization ontology) and the *treatment system* (corresponding to the response ontology, that is to say, the treatment system ontology and the collaborative process ontology).

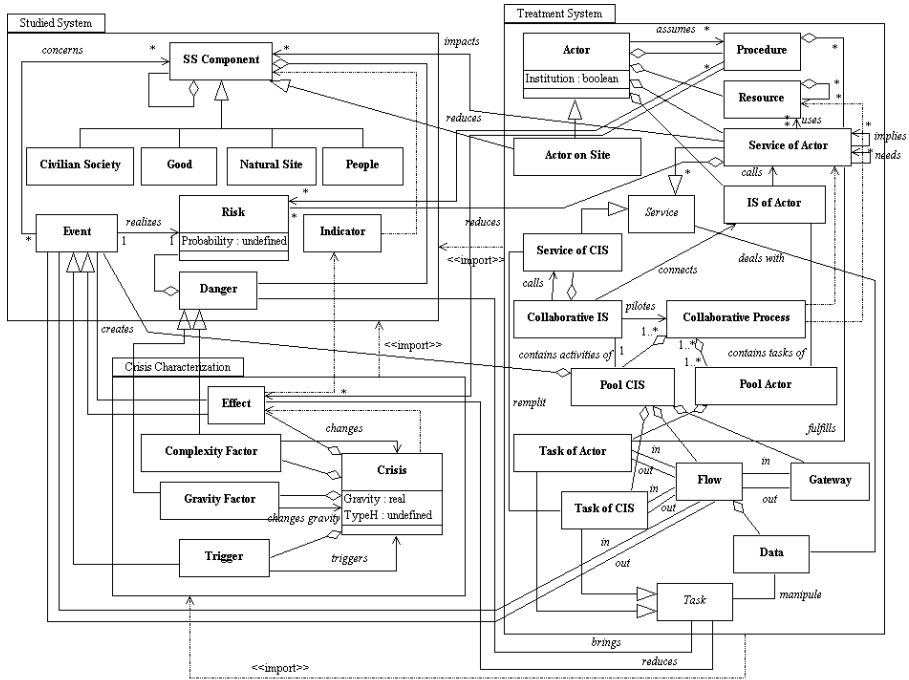


Fig. 3. A proposal for crisis metamodel.

- The studied system:

The studied system is defined as the sub-part of the world affected by the crisis. The components of this subsystem have been grouped in different categories such as *goods*, *natural site*, *people* and *civil society*. All those elements are considered as *studied system components* which can be concerned by the situation.

Goods can be seen as each man-made entities (roads, bridges, buildings, houses, etc.). On the opposite, *natural sites* are the elements of the studied system which are not man-made, such as rivers, forests, etc. *People* concerns all the group of persons which are threatened by the crisis situation (people of a city, group of travelers, employees of a company, etc.). *Civil society* includes legal entities (media, intellectuals, etc.), associations and organizations which act in the crisis area.

The studied system contains also *risks* and *dangers*. A *danger* exists continually (on the studied system) and one or several *risk(s)* may concretize the exposure to this *danger*. For instance, an area like US West-Coast presents a *danger* of seismic instability while an earthquake occurrence is a *risk* attached to this *danger*.

- The crisis characterization:

Crisis includes several elements: some (dynamic) are involved in its occurrence or its evolution while some others (static) are dedicated to its description. *Crisis* occurs due to one (or several) *trigger(s)* and, once appeared, is composed with three main components: (i) *effect(s)*, (ii) *complexity factor(s)* and (iii) *gravity factor(s)*.

A *trigger* is a kind of *event* which starts the crisis. It is the realization of a *risk*. An *Effect* is the noticeable consequence of the studied crisis. It is also considered as an *event* and can produce other *effects*. It can be evaluated through indicators. A *complexity factor* is a *danger* which impacts directly the nature of the crisis and can affect its type (for instance, a sanitary crisis may evolve into a social crisis due to the “over-communication” through media). A *gravity factor* is a *danger* which impacts directly the gravity of the crisis (for instance, a strong wind and a dry weather could affect the gravity of a fire in a forest).

- The treatment system (including collaborative processes):

In order to solve (or at least to reduce) the crisis situation, it is necessary to define a treatment system which aims to drive the situation to a stable and handled state. This treatment system includes *actors* (*institutions* or not, on the site or not), their *resources*, the *services* they provide, their *procedures*, their *ISs*, the *MIS* (named *Collaborative IS* on Fig. 4) and the *collaborative process* it should run. The bottom part of this package is dedicated to collaborative process description (it includes elements of process modeling) and is directly inspired from a metamodel of collaborative process described in [5].

4 Instantiation of an Example

In order to test the metamodel, we propose to instantiate it on a specific case of study: a NRBC exercise (27th of February 2004) managed by the *Prefecture du Tarn*²⁶ in France.

4.1 Brief Description of the Studied Case

The played scenario is the following: “At 10 AM, the 27th February 2004, the police is informed of an accident between a tanker truck (unknown substance) and a wagon containing chemical products (materializing a cloud). The sent policemen and the around employees of the railway station fall unconscious while several children of the near kindergarten (outside when the accident happened) feel sick.”.

²⁶ *Prefecture du Tarn* is a French institution in charge of representing the government authority on a local scale (they are among one hundred of *prefectures* in France).

4.2 Model of the Case of Study Using the Crisis Metamodel

We used GME (Generic Modeling Environment, 2005) to describe and store the crisis metamodel. This software tool allows us to describe a model relating to the designed metamodel (with specially chosen graphical icons). The following pictures (Fig. 4 and Fig. 5) present the packages *studied system* and *crisis characterization* of the instantiated model of NRBC crisis.

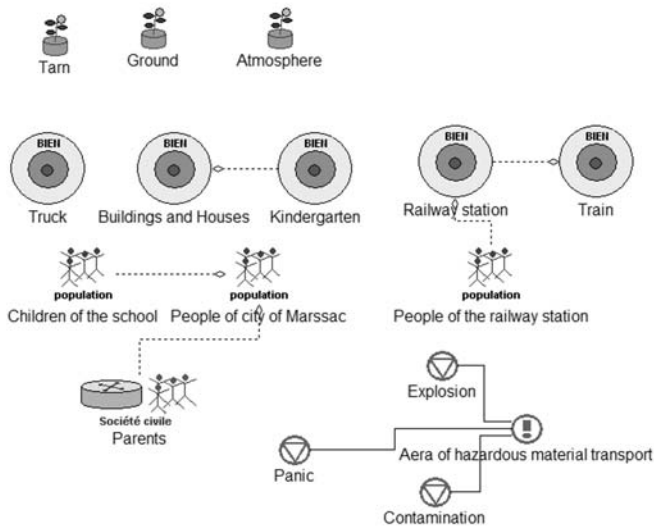


Fig. 4. Studied system

This part of the model contains three *natural sites*: the *Tran river*, the *ground*, and the local *atmosphere*. It contains also five *goods*: the *railway station*, the *kindergarten*, *buildings and houses*, the *truck* and the *train*. There are four kind of *people*: *people of the city of Marssac*, *people of the railway station* (travelers and employees), *children of the school* and their *parents*. *Parents* are also the *civil society*. Finally there is one main danger which is *area of hazardous material transport* and three identified risks associated: *explosion*, *contamination*, and *panic*.

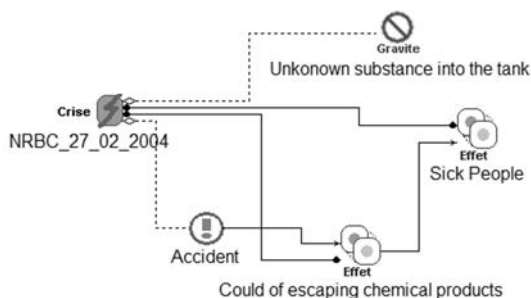


Fig. 5. Crisis characterization

As for the crisis characterization, there is one crisis: NRBC_27_02_2004, one trigger: accident between the truck and the wagon, one factor of gravity: the fact that the truck is carrying a tank with unknown substance and two effects: a cloud of escaping chemical products and several sick people (policemen, employees of the station and children).

This kind of obtained model can be seen as the basic result showing how the ISyCri ontology instantiation will be performed. According to Vatcharaphun Rajsiri works (see [3]), the main principle is to find a particularly strong links between components of the first ontology (crisis ontology in our case) and the second ontology (response ontology in our case). Then this “bridge” can be use to start the deduction mechanism. For instance, in Mrs. Rajsiri works (concerning ontology of industrial collaborations in order to deduce industrial collaborative process) a strong link exists between objectives of the collaboration and business services provided by partners. Defining needed business services from the expected objectives allow the inference procedure to instantiate a lot of complementary elements of the expected collaborative process. Similarly, in our crisis context, there are strong links between effects and services or risks and procedure, etc. It is this kind of transverse connections which could permit the fulfilling of the collaborative process part of the ontology (exactly as shown in [3] or as exposed in works on strategic alignment such as [9]).

Furthermore, the crisis characterization should be an iterative activity (in order to complete the representation and to follow the crisis evolution). It is so necessary to include a friendly-user requirement for the characterization method (and the illustration tool which will be prototyped). This aspect is a crucial point of the remainder of the project due to the essential will of flexibility of the approach. The iterative aspect of crisis modeling is one component of this expected flexibility.

5 Future work

As shown before, the use of semantical links between the two ontology (*crisis ontology* and *response ontology*) is the first step of MIS determination. So the next

step consists in determining these semantical links. For that, the authors use real situations : one situation of a civil crisis (*NRBC exercise*), one situation of a humanitarian disaster (*earthquake of Yogyakarta*), and one situation of a terrorist attack. Through the study of these examples, the authors try to determine the deduction rules between the crisis characterization and the collaborative process. This step is based on similar works on collaborative process deduction from industrial situation characterization (see [3]).

Once these semantical links known, the largest part of work will be to bring flexibility into the MIS process engine.

6 Conclusion

This article presents the French *ISyCri* project, its contents, its objectives and its first orientations. *ISyCri* deals with the topic of integration of partners trying to solve a critical situation. This integration matter is tackled through the angle of ISs interoperability. The project propose to include a mediator (MIS for Mediation Information System) between partners in order to support the required interoperability functions (such as data transmission, application management and collaborative process orchestration). *ISyCri* finally aims to provide a design method of this MIS. It is noticeable that this project is structured with three main parts: (i) crisis characterization and deduction of collaborative process through ontology mechanism, (ii) study of the technical architecture of the mediation information system and (iii) study and experiment on flexibility of the MIS (should the MIS be re-designed when the crisis changes? Should it be adaptable?). It is obvious that in a crisis context, the notion of adaptability or flexibility of the MIS is an unavoidable requirement. The real question is “how to include flexibility and eventual loops of evolution in the MIS design method?”. The answer to this question is a crucial issue of the project and a PhD have been started on this topic. It seems that ontology and the associated deducing process offers a strong basis to challenge this question. Indeed, the authors believe that maintaining a relevant situation model among the duration of the crisis can be the first step to global flexibility. Upholding a right vision of the situation is necessary to maintain the right support for its resolution. The metamodel presented in this article is the first result of this task.

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