A Metamodel and its Ontology to Guide Crisis Characterization and its Collaborative Management

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ABSTRACT

This paper presents a research in progress about the French *ISyCri* project that aims at providing partners involved in crisis management with an agile Mediation Information System (MIS). Not only this MIS shoul support the interoperability of the partners' information systems but it is also dedicated to coordinate their activities through a collaborative process. One of the first and main steps towards such a MIS, is to elaborate a common and sharable reference model built to characterize crisis situations. Such a model is also an input for automated reasoning to elaborate and adapt a crisis solving collaborative process. This article presents the objective of the project, our approach and our first results: a UML metamodel of crisis situation and its corresponding OWL ontology on top of which deductions are possible.

Keywords

Crisis, characterization, metamodeling, ontology, collaborative process, information system, system of systems.

INTRODUCTION

In a crisis[1] context (natural disaster, crash, conflict, industrial accident etc.), different actors from different organizations (medical units, police, NGO, etc.) have to work simultaneously in a hurry. Their ability to coordinate their actions is an essential point to reach their common goal: crisis reduction. The main objective of *ISyCri* (*I*nteroperability of *Sy*stems in *Cri*sis Situation) project is to provide partners involved in such a situation with a *Mediation Information Systems* (MIS) able to federate their respective heterogeneous and autonomous Information Systems (IS) into a global System of Systems (SoS) enacting to reduce the crisis through an adequate collaborative process. This MIS, acting as the linking support between ISs has to meet the two following 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 – possibly changing – group of involved partners working on the crisis (in order to ensure *flexibility*). Thus the MIS design should deliver an *agile* result (*agile* can be seen as the result of *responsiveness* and *flexible*).

ISyCri is a project supported by the French Research Agency (*ANR*[2]) involving five main partners: two companies and three academic labs. Institutional partners are also providing their user point of view. This project has been carried out since May 2007 and will end in May 2009.

In this context, we believe, that *integration* of partners is a crucial step on the way of success in crisis reduction. Our point is to propose to solve this *issue of integration of partners* by the way of *ISs interoperability*. According to *InterOp*[3], *Interoperability* is the *ability of a system or a product to work with other systems or products without*

[1] In this work, crisis are considered as events occurring suddenly. Long time crisis are not taken into account.

[2] *Agence Nationale de la Recherche*: French national agency for research.

[3] InterOp is a European Network of Excellence (NoE) dedicated to interoperability issues.

special effort from the customer or user. Finally, *Interoperability can be seen as the ultimate collaborative maturity level (of organizations) adapted to integration, which can be seen as the ultimate collaboration level (of network).*

Ensuring partners' ISs interoperability is not a trivial issue. We believe it is rational to tackle this topic on the basis of existing partners' ISs (and not to rebuild partners' ISs). The goal of ISyCri is to provide a method for MIS design. The general view of this design method is shown on next figure (using the "Y" of the MDA[4] approach):

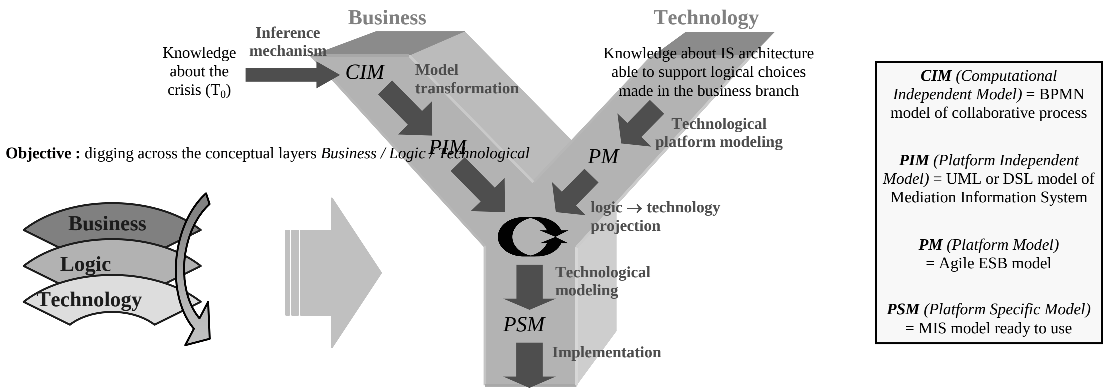

Figure 1. MIS Design proposal in the MDA context.

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 should be enriched). This step is based on the adaptation of results about deduction of collaborative process model (in industrial context) from collaboration characterization (using ontology) presented in (Rajsiri, Lorré, Bénaben, Pingaud, 2007). A model transformation mechanism use this *CIM* to build the logical view of the MIS: the *PIM*. This mechanism is directly inherited from (Touzi, Bénaben, Lorré, Pingaud, 2007) and proposes a SOA[5] structure for the MIS. Concurrently, the targeted technologic platform is modeled: the *PM*. Next, a projection (logic to technology) provides a MIS computable model: the *PSM*.

This article, as a work in progress, is focused on crisis modeling, as a way to build the first step to MIS design. The *ISyCri* project plans to set up a global crisis metamodel. This metamodel can be seen as the combination of two parts: one for crisis characterization and one for crisis treatment. The knowledge supplied by the instantiation of this metamodel can be used, first to model the adequate MIS to react promptly and second to maintain the model of the crisis in order to follow its evolution. Considerations about risks and crisis management are presented in section two in order to introduce this metamodel. Ontological objectives and mechanisms will be shown in the third section.

CRISIS SITUATIONS STUDY

The notion of crisis is a manifest component of the ISyCri project. It is especially necessary to link it with the concept of risk. Reducing the severity of crisis by supporting collaborative processes (through partners' ISs and a MIS) implies to identify the required knowledge to design this MIS. The objective of this study is to provide a covering and appropriate approach for crisis modeling. Information embedded into the model should be exploitable, particularly to deduce the relevant collaborative process and then to build the right MIS supporting this process.

Building a "crisis metamodel" might be a convincing first step to create a dedicated "crisis ontology" which may be able to support reasoning mechanisms. These mechanisms are the roots of the deduction of collaborative process (needed to build the right MIS).

From risks to crisis management

The notion of risk is very intuitive but its definition is not. The ISyCri project defines the risk as *the possibility of the occurrence of an event having positive or negative consequences. Risk is characterized by two dimensions: its*

[4] Model Driven Architecture is a model-based approach to design system, which separate business and technology.

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

probability and the measure of its potential effects (NB: Danger exists continuously but risk appears only if there is exposure to a danger). This definition meets the PRIM[6] vision which identifies five types of risks:

- Natural risks (landslide, fire, flood, hurricane, hearthquake, etc.),
- Technological risks (industrial accident, nuclear accident, biological accident, etc.),
- Collective transport risks (people or material),
- Everyday life risks (car accident, accident at home, etc.),
- Risks linked to conflicts.

The PRIM defines crisis as the realization of a major risk, due to the occurrence of a specific event and the presence of affected stakes. We believe that the happening of the specific event must be correlated with the presence of a danger. The following picture illustrates the links between the concepts of *crisis*, *danger*, *risk*, *event* and *stakes*.

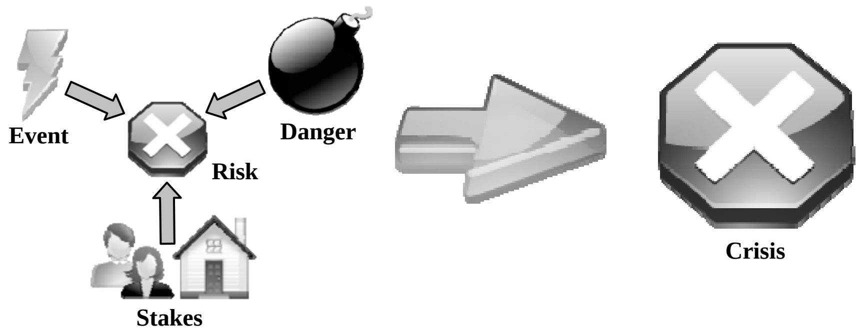

Figure 2. Notions of Risk, Danger, Event, Stakes and Crisis.

The French ministry of ecology produced a classification of damages which allows to categorize situations from incident to major disaster (kind of logarithmic scale).

Class of situation	**Human damage**	**Material damage**
0. Incident	No injured person	Less than 0.3 M€
1. Accident	1 to several injured persons	Between 0.3 M€ and 3 M€
2. Grave accident	1 to 9 dead persons	Between 3 M€ and 30 M€
3. Very grave accident	10 to 99 dead persons	Between 30 M€ and 300 M€
5. Disaster	100 to 999 dead persons	Between 300 M€ and 3000 M€
6. Major disaster	More than 1000 dead persons	More than 3000 M€

Table 1. Situations classification using human and material damage (from French ministry of ecology).

That classification provides a usable scale and allows to distinguish several classes of situations. However, it seems to be very “artificial” and “rigid” (especially due to the little number of factors it takes into account). Furthermore, it is crucial to notice that if *damage* can be considered as an obvious and implicit component of crisis, it is not the factor which imply to categorize a situation as crisis. It is rather the *unpredictability* and the associated *lost of control* which are the initial factors of crisis identification. ISyCri project define a crisis as *linked to the perception of an abnormal situation, which is a break into the expected evolution of the situation (standard, planned or at least*

[6] PRIM is a French institutional web site for major risks prevention (see http://www.prim.net/)

acceptable) of the world or part of the world concerned by the phenomenon ("the studied system"). A crisis may evolve and change and could be characterized through three dimensions: its gravity (damage measurement), its complexity (type of crisis, comparable to human responsibility degree) and its perimeter (the size of the studied system. The next part of this article will use this definition to propose a metamodel of crisis able to provide an exploitable basis for crisis characterization.

A Generic crisis metamodel

Crisis can be seen as complex system which has to be considered globally. Furthermore, to study and work on these situations, it is crucial to formalize the knowledge collected in order to exploit it. Due to the heterogeneity of crisis situations (humanitarian, civilian, military, hybrid, etc.) we propose to build a metamodel. A metamodel is (i) a model which instances are models and (ii) the representation of a model done using a model (Bataille and Castellani, 2001). The ISyCri metamodel is currently being tested, especially through specific instantiations (Truptil, *et al* 2008), (Lauras, *et al* 2008), but it can be considered as stabilized.

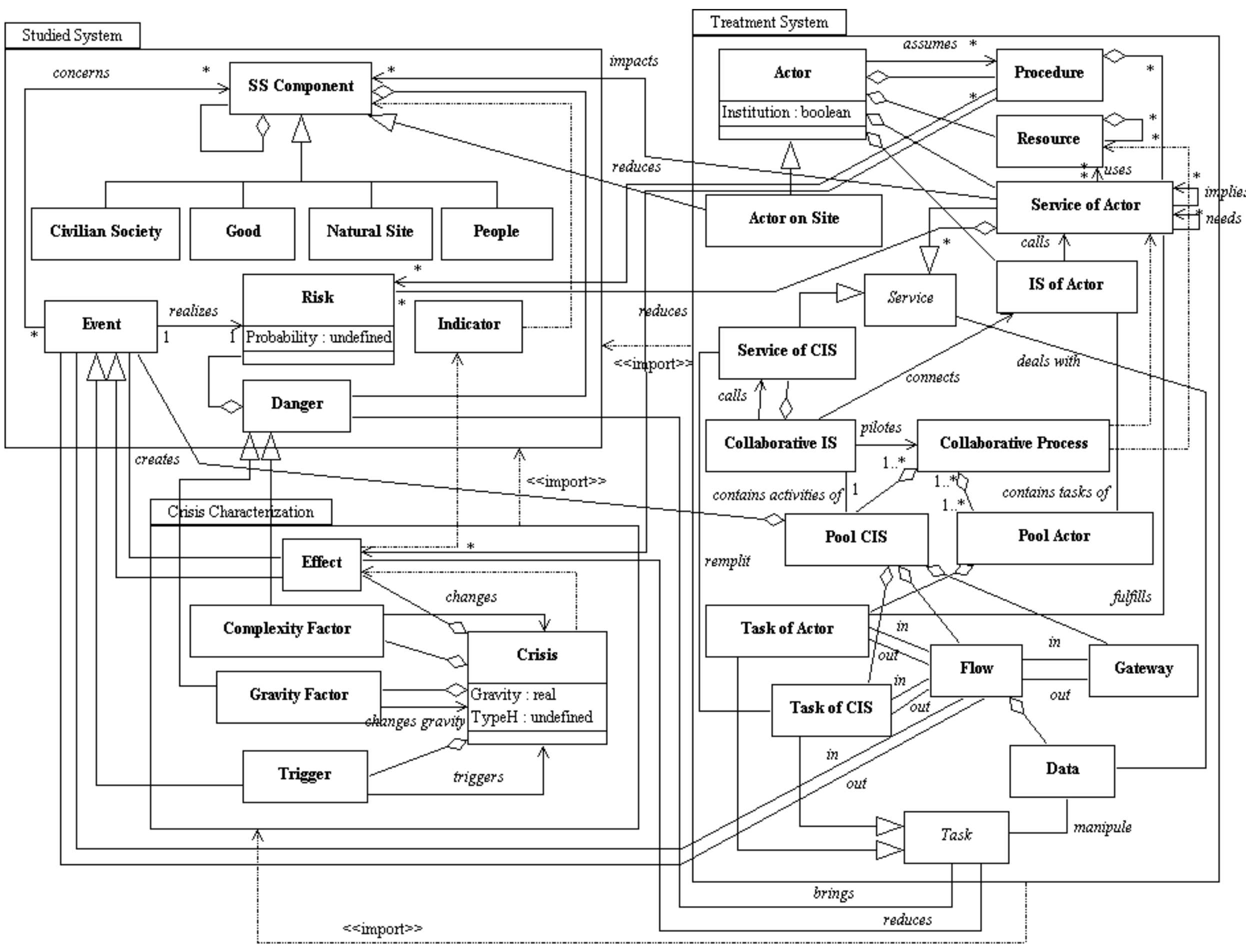

Figure 3. Crisis Metamodel (ISyCri 11/2007).

This metamodel is composed of three interrelated subsystems: (i) the studied system, (ii) the treatment system and (iii) the crisis description.

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 treatment system

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 Figure 3) 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 (Touzi *et. al*, 2007).

The crisis description

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).

ONTOLOGICAL TREATMENT OF CRISIS SITUATIONS

In order to use efficiently and as completely as possible the knowledge collected into one instance of the proposed metamodel, we propose to use ontological mechanisms recognized as a suitable way for knowledge management (Dieng, 2006) and (Missikoff, 2006). An ontology is a *formal and explicit description of concepts dedicated to a particular field or domain, of properties and characteristics of those concepts and of relations between those concepts*. These concepts may be instantiated in order to create a concrete knowledge. From a graphic point of view, an ontology can be represented with a graph which nodes correspond to concepts and which links are relations between these concepts.

According to (Ushold and Gruninger, 1996a, 1996b) an ontology may cover four level of formalization (informal, semi-informal, semi-formal and formal), three distinct uses (communication mean, exchange format and system engineering) and three categories of domains (vocabulary, problem solving and knowledge management). In the present case, the ontology used should be *formal* (in order to support deduction mechanisms), dedicated to *system engineering* (MIS design) and suitable for *knowledge management* and *problem solving*. That is why we choose the OWL-DL[7] ontology language.

ISyCri Ontology

The following picture presents the global structure of the proposed crisis ontology. Its design is based on the UML crisis metamodel of the previous section. 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 (Gruber, 1993) 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,

[7] Ontology Web Language based on Description Logic: Language based on description logic which allow to describe and reason on knowledge (subpart of first order logic).

excluding any implicit behavior of the system in order to provide a full model usable by the inferential services we planed 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 a more expressive power and is the only one which ensures computational completeness and decidability: it is fully usable by computers program.

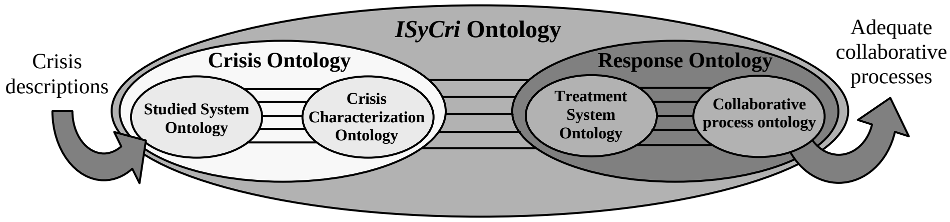

Figure 4. Ontological architecture of the deducing mechanism (sub-ontologies and links).

This ontology has been drawn using *Protégé*[8]. In *Protégé*, generic concepts are encapsulated into the *Terminological Box* (*Tbox*) while instances are encapsulated into *Assertional Box* (*Abox*). The knowledge base is composed with those *ABox* and *TBox*. Reasoning task concerns both the ABox and the TBox. The reasoning tool *Jess*[9] is also used to execute SWRL[10] Horn rules in order to deduce knowledge from this ontology. The following subsection presents this deducing principle on an example.

Deduction of a set of services from a crisis characterization (NRBC Example)

We propose to instantiate the ISyCri Ontology with a specific case of study: : A *NRBC* Exercise (27th of February 2004) managed by the *Prefecture du Tarn*[11] in France. The scenario was the following: "*At 10 AM 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 of Marssac fall unconscious while several children of the near kindergarten (outside when the accident happened) feel sick.*".

The tool GMF (Generic Modeling Framework) allows us to describe the crisis metamodel and to build models:

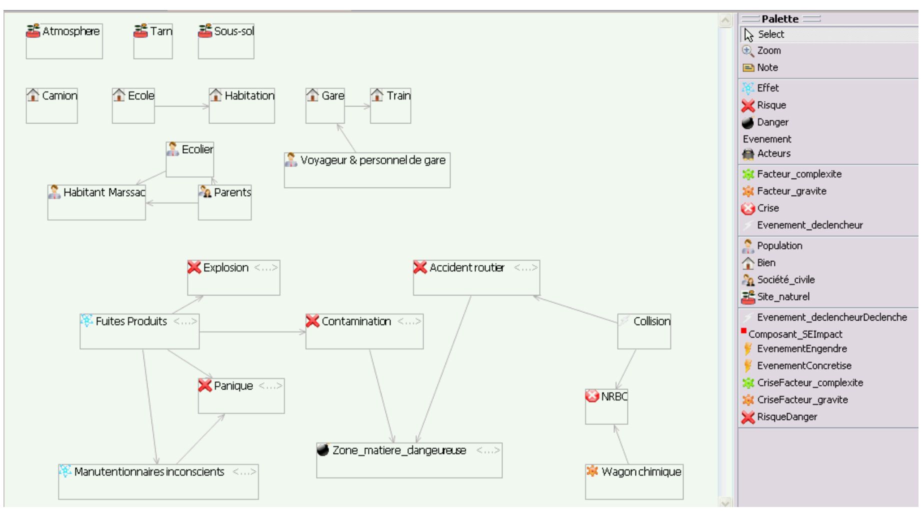

Figure 5. NRBC Crisis model built with GMF.

This part of the model contains three *natural sites*: the *Tarn river*, the *ground*, and the local *atmosphere*. It contains also five *goods*: the *railway station*, the *kindergarten*, *buildings*, the *truck* and the *train*. There are four kind of

[8] Open-source ontology editor developed by Stanford University. http://protégé.stanford.edu/

[9] Open-source inference tool frequently used with *Protégé*.

[10] Semantic Web Rule Language.

[11] *Prefecture du Tarn* is a French institution in charge of representing the government authority on a local scale.

people: *inhabitants of Marssac*, *travelers and employees of the railway station*, *children of the school* and their *parents* which are also the *civil society*. There is one main danger: *area of hazardous material transport* and four identified risks associated: *explosion*, *road accident*, *contamination*, and *panic*. There is finally one *crisis*: *NRBC*, one *trigger*: *accident between the truck and the wagon*, one *factor of gravity*: *the unknown substance carried by the truck* and two *effects*: *a cloud of chemical products* and *several sick people* (policemen, employees and children).

The XML file generated by GMF is then extracted in order to be injected (as an instantiation of ISyCri Ontology) into *Protégé* to start the reasoning step. The main objective of the reasoning phase is to deduce from crisis characterization one embryonic model of collaborative process that might be deployed to reduce the criticality of the situation. This emergent process model should, at least, include a list of activities required by the effects and risks identified (according to the involved actors' capabilities). Furthermore, some activities might need some other (before or after) in order to be efficient (for instance, a road might have to be closed in order to act on a fire). Some activities could also be incompatible (for example intervention of people on the ground and water dropping from fire-fighting plane). Some action might also generate some new danger, risk or effects which should also be taken into account (for instance, using water on a fire could increase the risk of land-sliding). The keystone of this goal is then the network of relations that may be designed into the ontology between the concepts of *effect*, *risk*, *danger*, *activity*, *mission of actor* in order to conduct the deduction procedure. This principle is based on (Rajsiri *et. al* 2007) which presents an approach of industrial network characterization to deduce collaborative process.

The following three SWRL rules illustrate this principle:

If a crisis model includes a risk, which is prevented by a service, then this service may be included into the model:

```
Risk(?y) ∧ Crisis(?z) ∧ hasRisk(?z, ?y) ∧ Service(?a) ∧ Prevent(?a, ?y) → hasPreventiveService(?z, ?a)
```

If a crisis model includes an effect, which is curated by a service, then this service may be included into the model:

```
Effect(?y) ∧ Crisis(?z) ∧ hasEffect(?z, ?y) ∧ Service(?a) ∧ Reduce(?a, ?y) → hasService(?z, ?a)
```

If an actor provides a required (curative) service then it should be included into the crisis model:

```
Crisis(?a) ∧ Service(?b) ∧ hasService(?a, ?b) ∧ actorHasService(?c, ?b) ∧ Actor(?c) → hasActor(?a, ?c)
```

The following picture shows the result of the deducing step of *Jess* and *Protégé* (based on fifteen real rules):

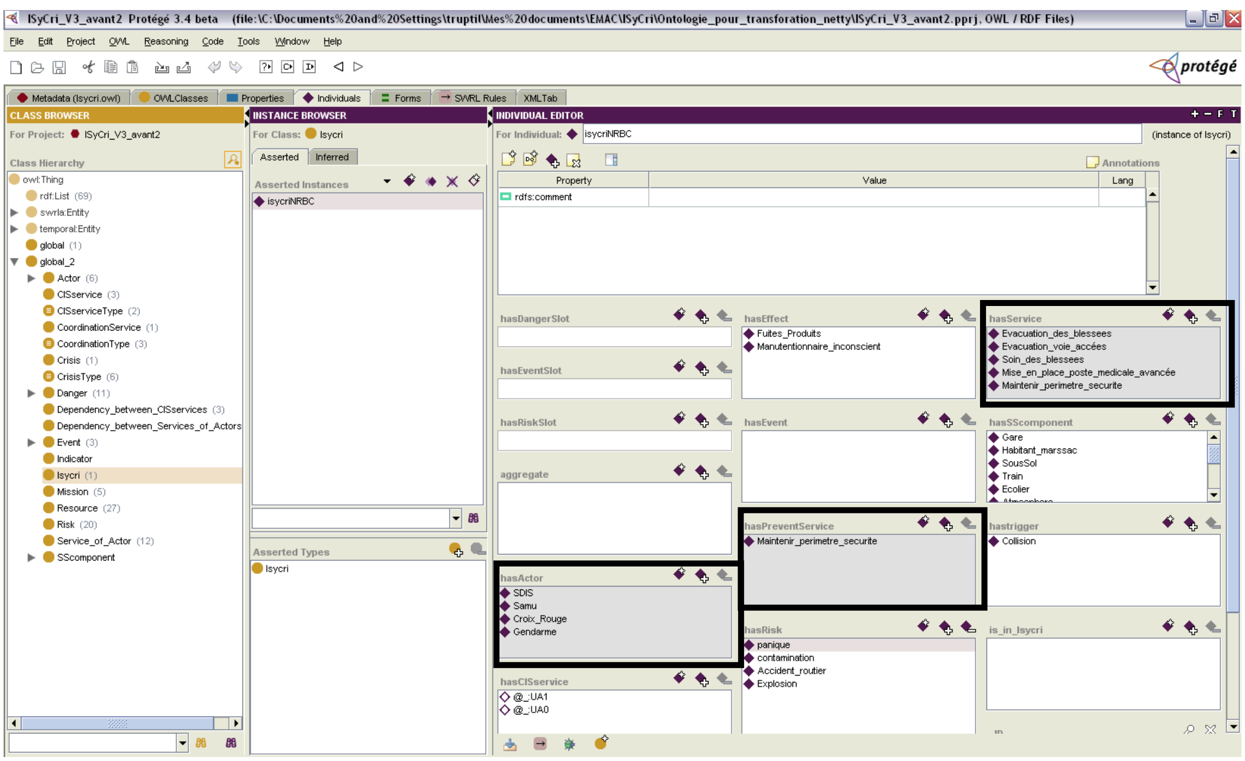

Figure 6. The obtained ontology of NRBC example after the deduction mechanism.

The framed areas of the previous *Protégé* screenshot contain the deduced elements: potential *actor* which may participate into the crisis reduction (because they provide a required preventive or curative service), *preventive services* which have to be done to protect the situation from inherent or new risk and *curative services* which have to be done to reduce existing effects (or to support, before, during or after, services which will reduce existing effects). Using these deduced elements, the embryo of collaborative process can be drawn. Indeed, each actor (including the MIS) is a partition (lane) of the process model which contains a set of services (activity). These activities are not yet organized on a chronological point of view but they are divided in two groups: *preventive services* and *curative services* (just called *services*).

PERSPECTIVES AND CONCLUSION

This article has presented the French *ISyCri* project, its contents, its objectives and its first orientations. *ISyCri* deals with the topic of integration of partners in charge of solving a critical situation. This integration is tackled through the ISs interoperability perspective. The project suggests 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 at providing a design method of this MIS. It is noticeable that this project is structured in 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 the MIS flexibility (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 has 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 determines the capacity 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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