A situation model to support collaboration and decision-making inside crisis cells, in real time

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ABSTRACT

Natural and man-made hazards have many unexpected consequences that concern as many heterogeneous services. The GéNéPi project offers to support officials in addressing those events: its purpose is to support the collaboration in the field and the decision-making in the crisis cells.

To succeed, the GéNéPi system needs to be aware of the ongoing crisis developments. For now, its best chance is to benefit from the ever growing number of available data sources. One of its goals is, therefore, to learn how to manage numerous, heterogeneous, more or less reliable data, in order to interpret them, in time, for the officials. The result consists on a situation model in the shape of a common operational picture.

This paper describes every stage of modelling from the raw data selection, to the use of the situation model itself.

Keywords

Crisis Management, Situation Model, Situation Awareness, Big Data

INTRODUCTION

For the IFRC[1], the term "disaster" has a number of different meanings: it refers to natural hazards and man-made hazards, from floods to industrial accidents and terrorist attacks. Their consequences on the core networks compel governments to involve many actors in the crisis response. Each stakeholder comes with its own procedures, often not adaptable to current events or ongoing actions, but suitable for the crisis.

Because of the interferences due to the coexistence of so many responses, officials have to make all stakeholders collaborate. This calls for a deep knowledge of the ongoing situation, while the crisis cells are running out of time.

To help them, the GéNéPi project has been set up. It aims to support both their situation awareness and the needed collaboration. It also gives the crisis cells the opportunity to benefit from as many data sources as necessary. The problem is that the data, coming directly from unknown, unreliable, heterogeneous sources, are, for now, raw and unusable data. The GéNéPi project idea is to turn them into instances of a known, suited model. This will generate a new model illustrating the ongoing situation that will (i) offer situation awareness to

[1] IFRC: International Federation of Red Cross and Red Crescent Societies

the officials, (ii) enable the GéNéPi system to generate and (iii) maintain an accurate business response process.

The first part of this paper presents the current needs for a situation model, in a crisis context. The second part responds to a specific problem:

How to turn an evolving set of raw data into a model, suited to all officials, whatever their acting zone, within a limited time?

Finally, the third part describes the three main uses of the situation model, made possible by the interpretation of raw data during a crisis situation.

THE NEED FOR AN AGILE COLLABORATION INSIDE THE CRISIS CELLS

A crisis situation well known by the French people

"Then, it was a huge disaster; it was 4 o'clock at night; the river was still rising, people suddenly invaded in their home had to seek refuge in their attic which was hit before long." (Maistrasse and Wiart 1846)

One of the biggest fears French authorities have involves the Loire River: a mixed flood, due to both sea and oceanic rainfalls, would affect eight French counties, in less than ten days. In 1866, Gien, *6.717 inhabitants ("Des villages de Cassini aux communes d'aujourd'hui" 2007),* knew a flow six hundred times higher than the regular flow. That year, 20% of the annual rainfall fell in three days and Jargeau, *2.578 inhabitants,* was devastated (Maison de Loire and DREAL 2011).

During the twentieth century no major flood happened in this area. According to experts, it is only a matter of time: the slopes, impermeable sub-grades and dikes of the area aggravate the risk of flood (Maison de Loire and DREAL 2011). And, when the water rises, will the authorities remember the past crisis and will they react quickly enough?

Many services involved in the crisis response

As widely acknowledged, the crisis management consists in four steps (Baldridge and Julius 1998) : the prevention, the preparation, the response and the recovery. This paper focuses on the preparation and response phases.

In France, a flood can be predicted two or three days ahead thanks to "Cristal" (DREAL 2010; Moulin and Thépot 1999). This official system provides hydrological models, meteorological radar images and reports aggregating information from diverse sources.

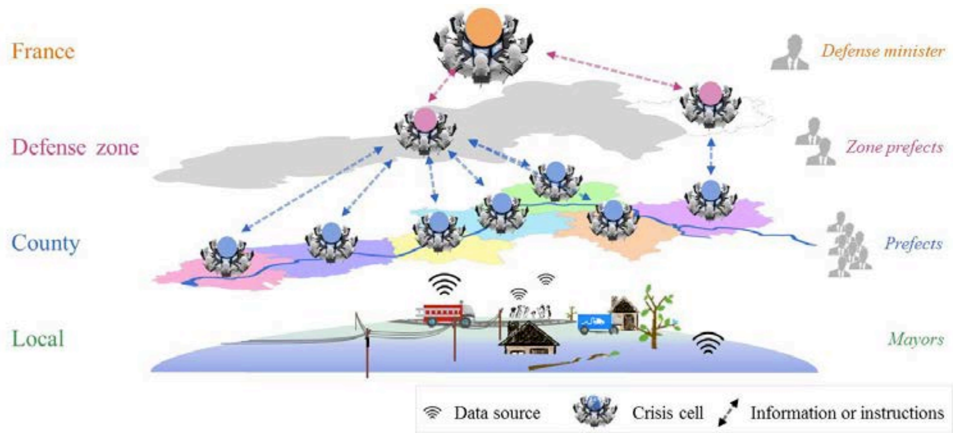

Figure 1 - Vertical granularity of crisis management in France

If needed, mayors will alert the population. They are in charge of the public safety and have to organize the response in their city, as the *prefects* for their county*,* the *zone prefects* for their defense zone and the *Defense Minister* in the country. Each of them sets up a crisis cell as soon as an alert is issued: they involve officials coming from the services, organizations and programs involved in the crisis response (cf. Figure 1).

A French law (Chirac et al. 2004) compels organizations; public, health and emergency services; medias; insurers; cities, counties, defense zones and ministries to prepare for potential crisis. But, when several plans apply, interferences happen. In order to avoid that, the crisis cells can make the stakeholders collaborate. Meaning that they have to (i) manage the different priorities, (ii) manage the communications and (iii) manage the network interdependencies, as well as make decisions and monitor the crisis situation.

The need for a situation model

Data represent the properties of objects and event, while information is deduced from them, as a description, an answer to simple questions like "who?", "what?" or "when?" (Ackoff 1989)

The GéNéPi project has been set up to support the crisis cells in making the stakeholders collaborate (cf. iii), in taking decisions (cf. i) and in following the crisis situation (cf. ii). Founded by a national agency, it gathers ten partners from academic researchers to industries and practitioners. The project, along with its system, is assessed once a year, by a steering committee that groups practitioners from all the middle Loire area. It offers to define, orchestrate and monitor the collaboration process: a set of coordinated actions executed by the stakeholders (cf. Figure 2**)**. To succeed, the project needs to be aware of:

- The stakeholders involved in the crisis response, their capabilities and the information that they can produce;
- The context, where the crisis struck;
- The ongoing developments due to the crisis.

This means that the GéNéPi system needs to collect data describing the partners, the environment and the events due to the crisis, and turn them into usable information. As a result, a model, called situation model, illustrates all the information deduced from a mining process (cf. Figure 2).

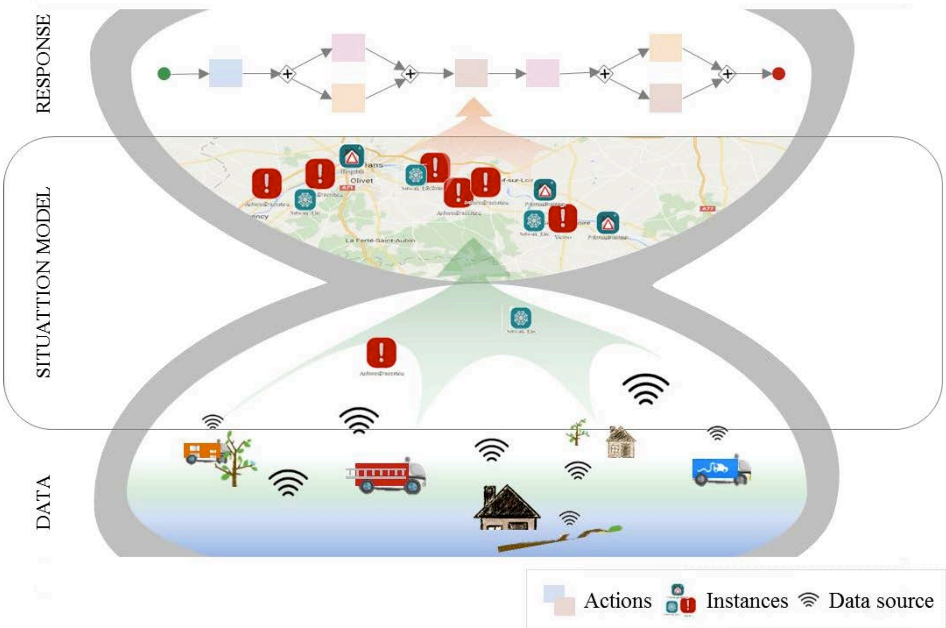

Figure 2 - The data and information life cycle imagined by the GéNéPi project's partners

The Information age as an opportunity

To describe and illustrate a flood, a lot of data describing the ongoing situation are needed. Hopefully, the electronic revolution and the digital age paved the way for a near-open access to real-time data.

The huge data volume and its variety

Many types of sources emit lots of heterogeneous data all the time (Gantz and Reinsel 2011; Ohlhorst 2012; Raghupathi and Raghupathi 2014) and during a crisis, such sources may be ordered by priority (Johansson 2015):

1. Official emergency management agencies: data coming from existing information system hosted by official services;
2. Official sectorial institutions : business information, known by some of the services involved in the response, can be communicated by phone, by e-mail, by walkie-talkies, by information systems and, even, by fax;

3. Relief or aid organizations: Information, as the one store in geographic information systems, can easily be updated by volunteers in near real-time: “Open street map” and “Google map marker” are widely used during crisis response (Ortmann et al. 2011);
4. Academic and scientific institutes: Histories of data are updated every day: for example, French floods are recorded in the BDHI[2] since the beginning of the 18th century;
5. Social media (not in Johansson but add here): Texts, audios, videos and images describing the consequences of the crisis are sent by ordinary people using, for example, Ushahidi or Twitter (Ortmann et al. 2011);

The speed necessary to process data in time

Such a tremendous data volume calls for high speed (Demchenko et al. 2013; Fayyad et al. 1996; Hashem et al. 2015; Kaisler et al. 2013): the system must be powerful enough to detect and integrate valuable data in time. For instance, a flow measure, which becomes irrelevant as soon as a new one arrives, has to be treated before the **expiry date** comes to an end.

The trust to put in data

All these sources cannot be trusted in the same way (Demchenko et al. 2013; Lukoianova and Rubin 2014; Rajaraman and Ullman 2012; Wu et al. 2014): some will be more or less biased, some not completely correct. For example, sensors have their own precision levels, journalists their own views, people their own beliefs, etc. Moreover, all these data travel from source to source, each one altering its original content.

THE GÉNÉPI INTERPRETER TO GENERATE A SUITED SITUATION MODEL, IN REAL TIME

In artificial intelligence, the GéNéPi system can be seen as an **agent** (Russell and Norvig 2009): it can perceive its environment, through the reception of **percepts**, and can act on the environment, through the orchestration of **coordinated actions**. As part of the GéNéPi project, the GéNéPi Interpreter[3] is responsible of the agent's situation awareness.

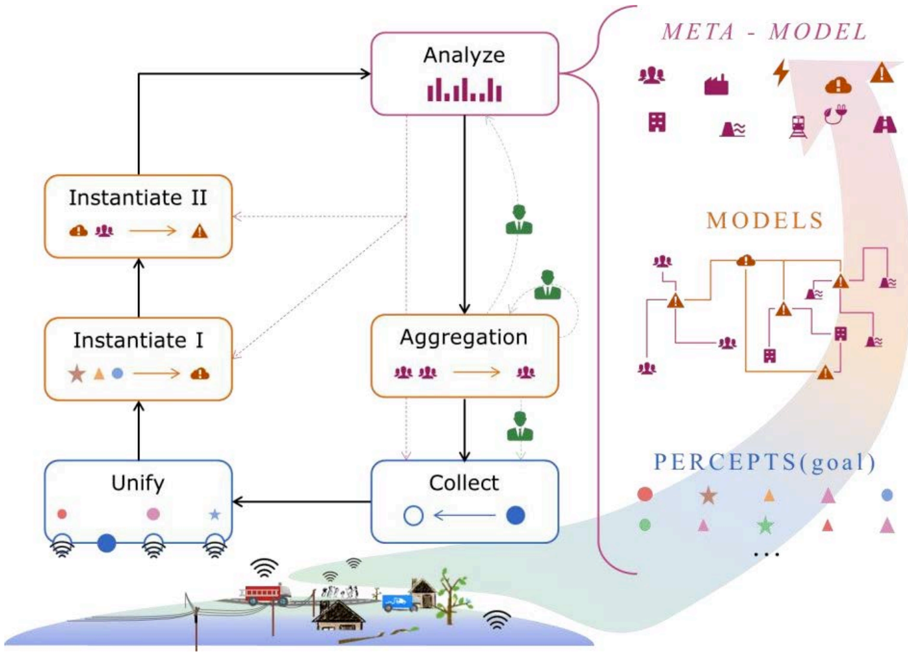

Figure 3 - The generation of a situation model that suits the decision-makers in a Big Data context

The GéNéPi Interpreter illustrates the ongoing crisis situation by instantiating a meta-model (common to all situation models). The *Meta-model* (Bénaben et al. 2016) is made of two types of concepts:

- *The first part of the Meta-model* can be instantiated mainly before the crisis, during the preparation

[2] French data base on floods, accessible at: http://bdhi.fr/appli/web/welcome
[3] The G. interpreter's real name was removed for blind review reasons.

phase. It concerns the capabilities of the stakeholders, willing to be involved or planned in a procedure, and the issues at stake in the area. Later on, during a crisis response, some unknown partners can emerge and new stakes can be identified: the model is completed along with the crisis developments.

- *The second part of the Meta-model* concerns the crisis itself: the danger, risks and events affecting the territory. An environment component is **hyper-vulnerable**, if the risk and its vulnerability to this risk are high (Anthony 1987).

For example, to represent the different hydrological regions of the Loire River, the system needs to list concepts (cf. Figure 4). There will be a watercourse, watercourse segments and dikes. Then, it will illustrate one region in particular by instantiating these concepts: for example, the "Loire River" passes through a city called "Orléans", located in the middle of the Val d'Orléans, and protected by a dike, called "Digue d'Orléans".

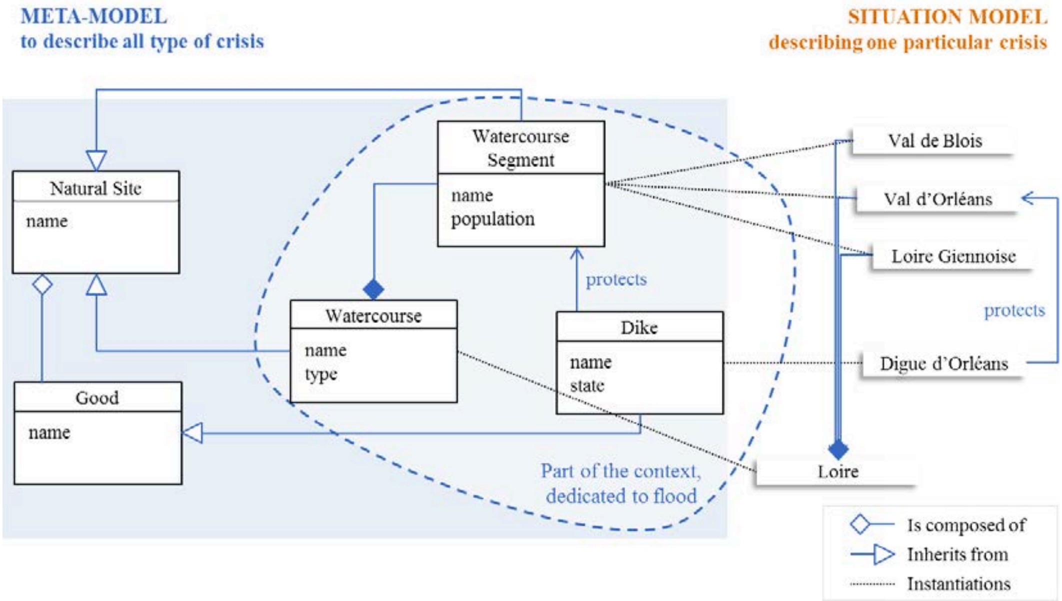

Figure 4 - The Meta-Model: a critical part of the Situation Model creation process

The goal of the GéNéPi Interpreter

The *Collect* module (cf. Figure 3) determines the goal of the Interpreter on a regular basis. It indicates which aspects of the environments are to be considered. The percepts – describing the crisis environment and perceived by the system – are thus, always suited to current priorities.

For example, at the beginning of the response, lower crisis cells try first to detect both the consequences and the risks due to the crisis. Thanks to them, upper crisis cells will be able to assess the magnitude of the crisis. In this case, the *Collect* module has to prioritize the collection of data that can be used to instantiate the *second part of the Meta-model*.

This function is critical (Endsley 1995) considering the amount of data to be processed in time.

The interoperability of all the Interpreter components

Data and information are received by the *Unify* module, under the *Collect* requirements. Information received from trusted, known sources can automatically be added to the situation model while the others are redirected to the *Instantiate* module (cf. Figure 3).

Inside the GéNéPi interpreter, issues soon arise due to the variety of data. This is one of the biggest obstacles to effectively make sense of a large data volume (Kaisler et al. 2013). To counter it, the *Unify* module automatically transforms the input data into XML[4] documents. These new data are **IT events**. They consist of: a date of creation, an ID, a topic, a geolocation and a description of the concerned **field events (cf.** Figure 5**).**

[4] Extensible Markup Language

From raw events to situation models

The *Instantiate* module aims to understand the meaning of the IT events: it links together disparate data to develop (Endsley 2015) the situation awareness of the system. This module is divided into two parts:

- *Instantiate I*, receives the events coming from the *Unify* module and turns them into instances of the *Meta-model.*
- *Instantiate II* deduces new instances directly from the situation model

When *Instantiate I* deduces a new flooding danger from the predicted evolution of the river, *Instantiate II* adds a new risk for each sensitive building threaten in the area (a danger brings risks on each stake in its perimeter). For example: a risk of victim will emerge for each household vulnerable to the flood; a risk of drop in power supply if a transformer is located in a flood area; etc.

```
<?xml version="1.0" encoding="UTF-8"?>
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema"
        xmlns="http://www.mines-albi.fr/LoireFloodingEvent"
targetNamespace="http://www.mines-albi.fr/LoireFloodingEvent"
        elementFormDefault="qualified">

        <xsd:element name="Event_ForecastMeasures">
                <xsd:complexType>
                        <xsd:sequence>
                                <xsd:element ref="Measures_ForecastMeasures" minOccurs="0"
                                        maxOccurs="unbounded" />
                        </xsd:sequence>
                </xsd:complexType>
        </xsd:element>

        <xsd:element name="Measures_ForecastMeasures">
                <xsd:complexType>
                        <xsd:sequence>
                                <xsd:element name="id" type="xsd:string" />
                                <xsd:element name="stationName" type="xsd:string" />
                                <xsd:element name="stationLat" type="xsd:float" />
                                <xsd:element name="stationLong" type="xsd:float" />
                                <xsd:element name="f_min" type="xsd:float" />
                                <xsd:element name="f_med" type="xsd:float" />
                                <xsd:element name="f_max" type="xsd:float" />
                                <xsd:element name="wl_min" type="xsd:float" />
                                <xsd:element name="wl_med" type="xsd:float" />
                                <xsd:element name="wl_max" type="xsd:float" />
                                <xsd:element name="date" type="xsd:dateTime" />
                                <xsd:element name="nbHours" type="xsd:string" />
                        </xsd:sequence>
                </xsd:complexType>
        </xsd:element>

</xsd:schema>
```

Figure 5 – XSD of the hydrological events simulated by the GéNéPi system, sent each day by the SPC (the French flood forecast service). There is one measure for each forecast and 54 hours of forecasts per event.

The monitoring of the Interpreter

One goal of the *Analyze* module is to forecast the future, in the shape of a new model, derived from the situation model. This model, called **projected model**, is produced by mixing the response process (cf. Figure 2), the predictable **natural progressions** of the crisis and the situation model together.

The 48h projected model can, for example, take into account: the evolution of water level and water flow, forecasted by the SPC (cf. Figure 5) or the fact that the risk of victim will be prevented thanks to an evacuation to be. 48h from now, the crisis cells will be able to compare this projected, expected model to the situation model updated in real-time. If the expectations did not suit to the reality, the crisis cells must adapt the on-going response (cf. Figure 7).

The other goal of the *Analyse* module is to monitor the **quality** (Wang and Strong 1996) of the percepts, of the models and of the *Meta-Model* (cf. Figure 3). To succeed, it looks for data in the whole system, in order to confirm findings, fill missing information or improve the veracity of the models. These iterations also enable the *Analyse* module to alert the administrator when one source or one operating rule is to be seriously questioned.

The users' point of view

The models contain so much information that the user needs to focus in terms of both granularity and scope. For example, instead of the name, function and geolocation of each potential victim, the crisis cell of the defense zone (cf. Figure 1) would prefer a quantity per county. However, a prefect would choose the other option.

The *Aggregate* module has been set up to adjust, in real-time, the models to each crisis cell. For the Loire River flood, this represents nine different points of view, from three main categories: county crisis cells, zonal crisis cells and national crisis cell (cf. Figure 1).

This module also deals with the rights and wills of officials. For instance, a crisis cell from the defense zone might want to know further details about a particular event resulting from the crisis. And, if this information has been classified by the national level, a formal authorization will be required.

THE SITUATION MODEL TO SUPPORT THE DECISION MAKERS

A common operational picture inside each crisis cell

The *Aggregate* module provides a common operational picture adapted to the expectations of each crisis cells. Once displayed, it illustrates both the situation and projected models with a point of view that fits the expectations of those present. The goal (Endsley 2015; Kaisler et al. 2013) is to provide with answers to "what is happening?" and "what is likely to happen next?", as fast as possible.

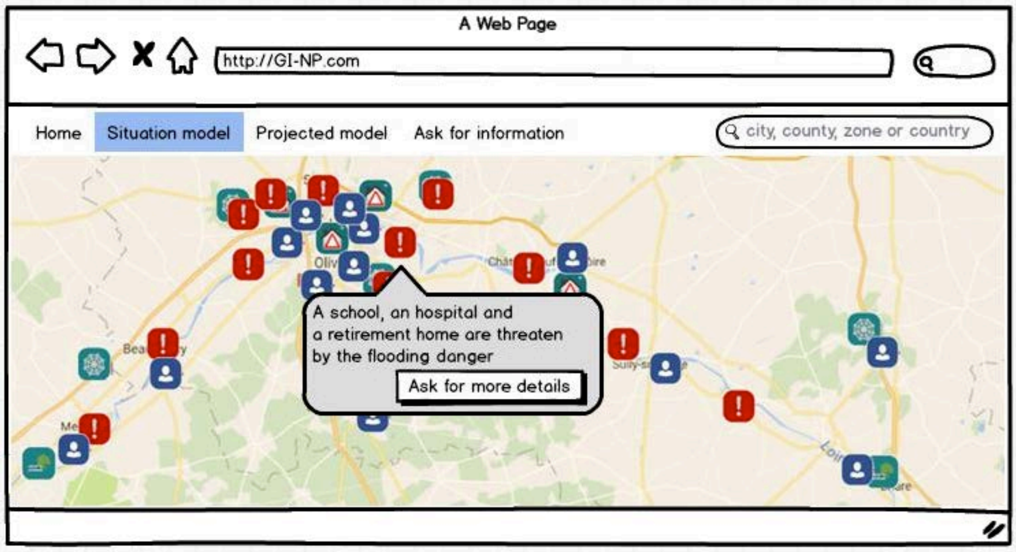

Figure 6 - Mockup of the future user interface, displaying the situation model

The common operational picture also significantly reduces the uncertainties and stress related to decision-making (Dautun and Lacroix 2013). The picture is displayed in a shape familiar to the stakeholders: a GIS[5] interface (cf. Figure 6).

A support to collaboration for the stakeholders involved in the response

The GéNéPi system uses the situation model to choose and coordinate the actions relevant to the response. The goal is to support the collaboration of the stakeholders in the field, to free up the decision-makers time. To succeed, it needs information on the available stakeholders and the element of context impacted by a risk, a danger or a consequence of the crisis. That's why, the GéNéPi *Meta-model* (cf. the example in Figure 4) covers these three parts: it ensures the completeness of both the projected and situation models.

The agility of the collaboration offered to the stakeholders

The response process, conversely to the models, cannot be updated in real time: it would require too much time. The idea is to detect the most suitable moment to launch an adaptation of the response process. In order to do that, the situation model is compared to the model, projected for this moment (cf. Figure 7). The distance between the two models is computed considering the importance and cost of the differences (Barthe-Delanoë et al. 2014). If the distance exceeds a threshold, a new response process is deduced.

[5] Geographic Information System

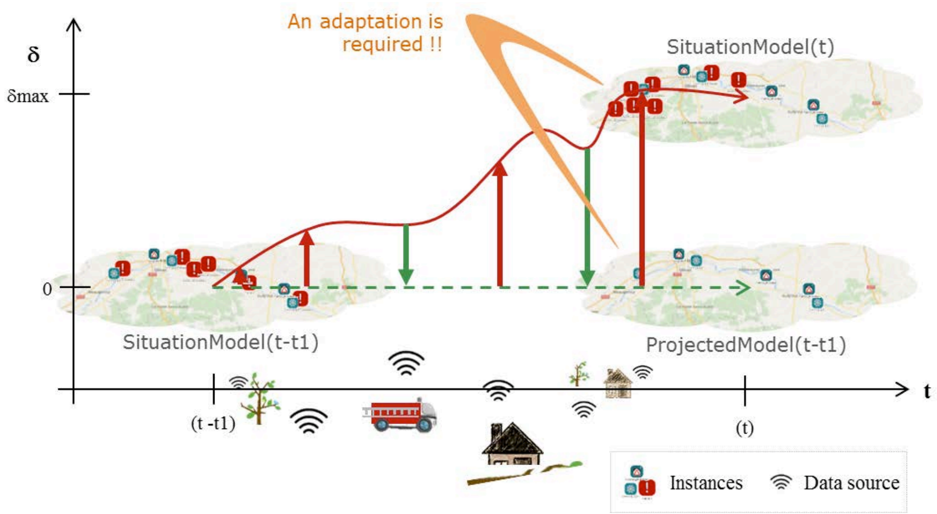

Figure 7 - Illustration of how the agility is computed in the *GÉNÉPI Interpreter*

CONCLUSION

Officials involved in a crisis response do not have time for taking new data sources into account, while it is the opportunity to take well-informed decisions. To support them the GéNéPi project offers to both support the collaboration of the stakeholders in the field, and the data management in the crisis cells.

The GéNéPi Interpreter, introduced in this paper, is a part of the GéNéPi system. It is dedicated to the collect, the interpretation and the use of raw data coming from trusted, available sources.

At the end of 2017, the GéNéPi system will be used for the first time in public. In 2018, several new scenarios will be tested. After the end of the project, the two PhD students of the GéNéPi project will continue to develop the different parts of the solution, including the GéNéPi Interpreter, and several new projects should take over the work next years.

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