Towards an Automatic Assistance in Crisis Resolution with Process Mining

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ABSTRACT

To deal with a crisis situation, experts must undertake a chain of activities, called process, to minimize crisis consequences. To assist the expert in making decision in crisis resolutions, authors propose a method aiming at discovering crisis response processes. This method is based on a two-step strategy: the first step classifies the system's traces, representing stakeholders' past actions, into different sets, where each one represents a set of response processes according to a specific context; the second step uses process mining algorithm to discover the corresponding response plan process model based on the obtained chain of activities for each previously classified context. These response plans will be a referenced aid for experts while making crisis resolution, according to each context. The proposed approach is illustrated on the traces issued from the crisis caused by the 2010 Xynthia storm in France.

Keywords

Crisis management, traces, response plan, clustering, process mining.

CRISIS RESOLUTION: SHOULD IT BE AUTOMATIC NOWADAYS?

Disaster and crisis are real challenges in a practical life. They often are unpredictable (Maryam & Kamran, 2016) and they may cause damage to human lives and have environment and economic consequences. According to (Nikolai et al., 2015), a crisis is defined as "*any event that threatens to, or actually does, inflict damage to property or people*". Crises can be small or large scale, they can happen at any time and their consequences can be very different (Nikolai et al., 2015). Crisis origins are extremely diversified Sauvagnargues, 2018), it can be natural (flooding, storm, *etc*.), environmental (fires, explosions linked to infrastructures, *etc*.), human (terrorism, arson, *etc*.) or technological (virus, computer failure, *etc*.). Few years ago a survey involving 1430 companies worldwide showed that "*despite a significant increase in risks from both external and internal sources, only 47% of companies consider that they are sufficiently prepared to the crisis situations*" (Leblond, 2004). More recently, in (Recovery, 2017) authors claim that "*companies that do not have a crisis management plan are far less able to minimize the crisis's impact*". Over the past few years, we realise that whatever the crises' origin is, the crisis's understanding and the reducing of its damage become more and more important. Moreover, the complexity and the dynamicity of crises make it difficult to understand crisis situation and to elaborate the most appropriate response to it.

To deal with this issue, the term of *crisis management* emerged at the beginning of the 20th century, but it had not been really used till the 1960s. The crisis management encompasses all tasks aimed at resolving crises and reducing their impacts. In the literature, the crisis management is structured in several phases. In (Tufekci & Wallace, 1998), authors proposed an approach with two phases: *before-crisis* and *after-crisis*. The *before-crisis* phase is a prevention and preparation phase that sets up an immediate response to resolve the crisis. The *after-crisis* phase consists in rebuilding and re-establishing the crises' damages. Another approach also involves two phases (Sundar & Sezhiyan, 2007): a *crisis phase,* aiming at mitigating and preparing for crisis occurrence, and

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a *response phase* that represents all of the actions needed to be carried out as soon as possible to face the crisis. Hereafter, we focus on the response phase in the process of crisis management.

In order to cope with crisis situation, different actors and resources need to collaborate to efficiently respond to the crisis. Actually, actors involved in a crisis resolution perform consecutively their activities following a coordination of the crisis situation called *response plan*. This plan is a kind of workflow that contains activity sequences performed by one or several actors during crisis situations. To model the response plan, many notations have been defined over the past few years. We have chosen BPMN (Business Process Model and Notation) as a notation language for end-users[2] (Object Management Group, 2011). BPMN is a powerful modelling method that can easily model complex real processes such as response plans. It provides a standardized matching between real processes and mathematical formalism that helps authors to be more flexible in manipulating and validating all kinds of business processes. Figure 1 gives an example of a process corresponding to a response plan that describes some prior activities to be carried out at the beginning of a crisis occurrence.
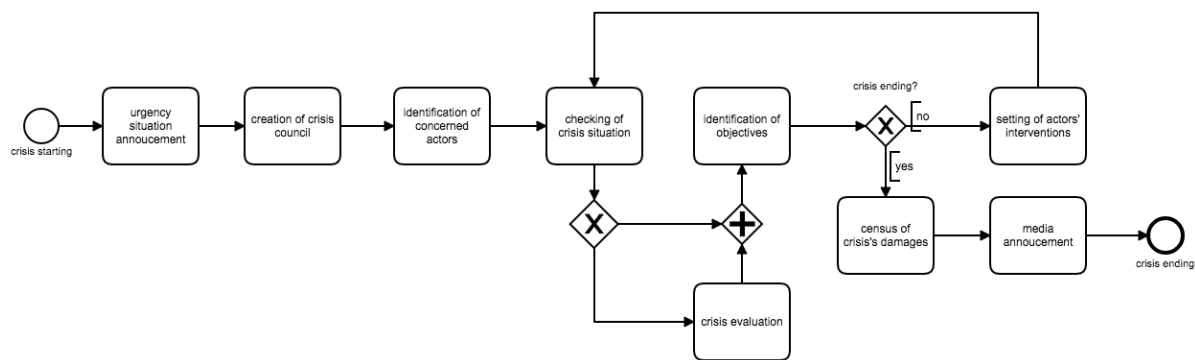

Figure 1. Example of response plan (BPMN) for first time of crisis situation

Crisis's experts are involved as soon as the crisis arise. They supervise the crisis to plan and they decide what should be done to resolve the situation. As depicted in the Figure 2, at each moment, a crisis context is observed. Experts choose a response plan to face the observed context and they must adapt this plan according to the situation changing. The adopted response plan is often based on experts' experience. They are trained to deal with the crisis situation and are able to decide the appropriate activities to carry out. However, there may arise sudden and unpredictable situations that experts have not forecasted. In that case, it takes more time to formulate a suitable plan according to the unexpected circumstances and the lack of immediate knowledge may be another impediment for real-time reactions in experts' decisions. Furthermore, the response plan should be tailored to specific circumstances of various situations that may locally occur during a crisis. As consequence, experts have to develop different response plans to face different crisis contexts.
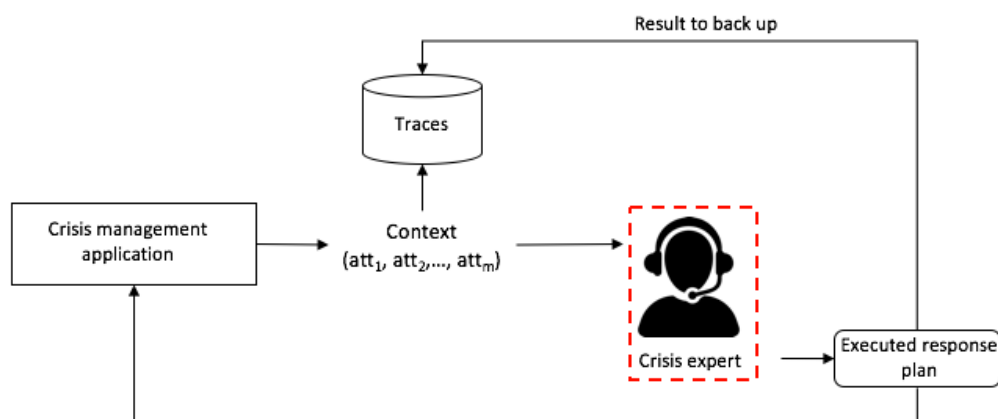

Figure 2. Expert's crisis participation in Crisis Management System

The aim of our work is to assist experts in their decisions. Authors propose an approach that helps experts design a response plan based on collected data from previous crises.

Authors assume that there is a crisis management system at the crisis time. This kind of system includes a database that records all observed events and performed tasks, called *logs*. Observation and evaluation of the

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[2] Throughout this research, all of the considered response plans will be denoted in BPMN format.

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recorded logs are often based on analysis of large volumes of data representing the contextualized information collected during system's execution, called *traces* (George et al., 2016).

- A *trace* is a sequence of data generated by any action regarding an object or an event occurring during system's execution. It is a set of temporally situated elements.

- Each trace can be associated to a model called *trace model*, that formally represents the corresponding traces. It contains the attributes concerned by the traces, as: *time*, *date*, *user id*, *performed action*...

- The component that allows to collect, handle and analyse traces is called a *Trace-Based System* (Settouti et al., 2009; Lebis et al., 2016).

The traces help us to analyse the previously performed workflow in order to discover the response plan applied at that crisis time. The question is: how to explore the recorded traces in order to get a response plan (workflow type) during the crisis's situation? *Process mining* (van der Aalst, 2016) emerges in the literature as possible response. It represents a set of techniques that could discover business processes from available traces. In our work, a process corresponds to a response plan to a crisis situation.

Authors intend to combine the two aspects introduced above, system's traces and process mining, in order to achieve their main objective: develop a method to assist crises experts in making a response plan at crisis time. The method combines technics from both domains in the crisis management issue. The paper especially focuses on the experimentation of the proposed approach on a real crisis to demonstrate its efficiency and its ability of producing a real-time response plan for crisis situations.

The paper is organized as follows. Next section briefly presents how the crisis resolution is made in the recent years. Then, the case study based on Xynthia windstorm crisis, occurred in February 2010, is presented. It will be used to illustrate the approach and to show its performances. The approach is explained just after, followed by some experimental results and discussion Finally, we conclude the paper and give some guidelines for further research.

HOW WAS CRISIS RESOLUTION MADE IN RECENT YEARS?

A response plan can be seen as a process composed of a set of ordered activities to deal with the crisis situation. The activities and their execution order are described in a predefined scenario or in available official plans. According to a given situation, a concrete response plan must be selected from a set of available alternatives and applied in order to solve the crisis. Over the last years, this topic has risen in importance. In this section, we will examine how responders do in a crisis situation and how to make a response plan to deal with it.

(Le et al., 2017) stated that an activity-oriented process is considered to make a response plan during a crisis. The obtained process model represents activities and exchanged messages between the actors involved in a crisis. Authors have used the α-algorithm (van der Aalst, 2011) to discover the process model from a log file. In (Kushnareva et al., 2015), the BPMN model is implemented to face the flood crisis. This model is predefined based on the collaboration between several actors involved in flood resolution, as the police taskforce, fire brigades, authorities for emergency situations, *etc*. Another application of this approach is used to represent the response plan to face the tsunami in Ho Chi Minh city (Thanh et al., 2013). Authors explain clearly the roles and the tasks of each stakeholder (local administration, local civil defence forces, communication unit, police and health units). The plan assures coordination between these actors. A common drawback in these approaches is that they are based only on textual documents. They specify how to face a crisis and then researchers model the available documents to build a response plan in a process-based notation. It is static and does not take into account past experience: what was done in previous crises and how the predefined procedures were adapted to a given crisis and its contingencies. It is an important source of knowledge that needs to be considered.

Concerning the use of past information to build a response plan in a crisis situation, few works address this issue. In (Negre, 2013), the author exploits the knowledge acquired in past experiences to recommend the best action to deal with the current crisis. A United Nations report points out that former experiences should be taken into account in order to improve the response plan making (United Nations, 2006). The use of past information is also mentioned in (Hanachi et al., 2016). Authors analyse the interactions collected from involved actors during the crisis situation. With this information, authors can discover a meaningful coordination patterns that reflect the organizational structure and the interaction protocols, which are part of the considered response plan. Authors have used process mining techniques (van der Aalst, 2016) with the extension of organizational and interactional dimensions. Another research aimed to discuss the application of process-based in emergent situation (Ariouat et al., 2016). Authors claimed that the collaborative processes in crisis management require a context description for process flexibility. They used the definition of context description in crisis management (Rosemann et al., 2008). Context is defined as the minimum of variables containing all relevant information that

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describes it. Context observation allows deciding what should be done to adapt actions to the current situation. Furthermore, a case study of disaster response and emergency management is presented in (Valcik & Tracy, 2017). Authors identify all actors involved in crisis response, but it is a manual work and it is still based on hard-copy documents describing the experiences from other crises experts.

To the best of our knowledge, very few researches deal with the problem of making a response plan in crisis situations. Building automatically such plans is the motivation of our research work. By combining different existing aspects in this domain, we propose a strategy, which is the main purpose of this article, aiming to discover a response plan for each crisis's context based on the recorded traces. We propose to combine two complementary points of view:

- The first one is to use the crisis context to differentiate activities performed by several actors involved in previous crisis situations.

- The second one is related to the use of process mining technics to discover the response plans. Based on the process mining, we can extract the set of response plans corresponding to different past crises' contexts. This set will be used to assist crises' experts during future crises.

The proposed approach is based on traces generated and collected during previous crises, we start by introducing the case study use illustrate our proposed methodology.

CASE STUDY: XYNTHIA WINDSTORM 2010

To illustrate our approach, we consider data sets collected during Xynthia crisis. It was a violent European windstorm that crossed Western Europe from February 27th to March 1st, 2010. In France, civil authorities consider Xynthia as the most violent storm since December 1999, at least 51 persons were killed, and 12 more said to be missing. It reached its highest warning level (red) for five French administrative departments: Charente-Maritime, Vendée, Deux-Sèvres and Vienne.

The Trace-Based System used by the fire-fighters allowed collecting various data. The data set records 274 interventions of fire-fighters for the Charente-Maritime and 277 interventions for the Deux-Sèvres. Each intervention may involve one or several vehicles depending on intervention contexts. In the sequel, we describe how the traces were collected and transformed.

Traces collection

In the considered crisis management application, experts interact with the system by controlling a sequence of activities to respond to the crisis situation. Observation and recording of crises' information has to be done exhaustively. Data retrieved from this step contains all information observed during a crisis. There may be information on the crisis location, information from the crisis operation centre. Besides, experts should choose one response plan according to the current context at each crisis moment. All of these types of data should be captured and analysed to extract the relevant information.
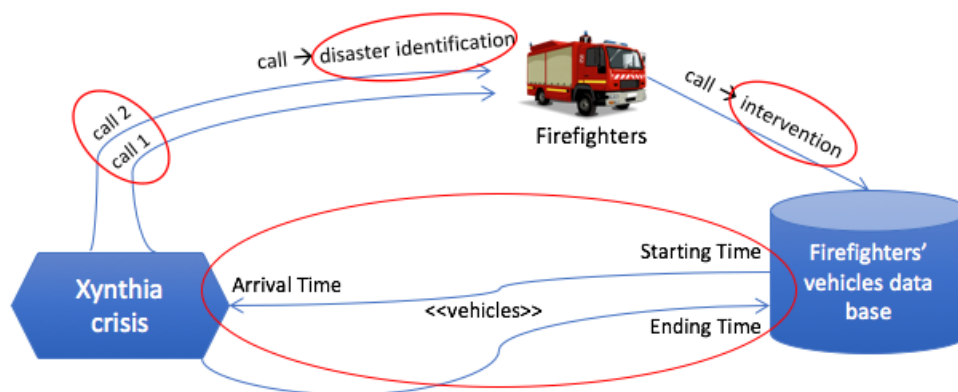

Figure 3. Traces collection in Xynthia crisis

For instance, Figure 3 describes the fire-fighters traces collection process of Xynthia crisis. Citizens and possible victims call the fire-fighter's switchboard to report about the disaster and possibly ask for help. The Fire-fighter's Operation Centre (FOC) receives the calls and based on the caller declarations identify the type of disaster or local crisis situation. According to its classification (*event type*, *severity level*…), FOC creates the corresponding intervention to resolve the reported disaster. Each intervention sends one or several vehicles to

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the crisis place to deal with the disaster. The set and the chaining of used vehicles are considered as the response plan for the FOC. Figure 4 gives the model of traces collected during Xynthia crisis. These traces are then used in the *transformation* step.
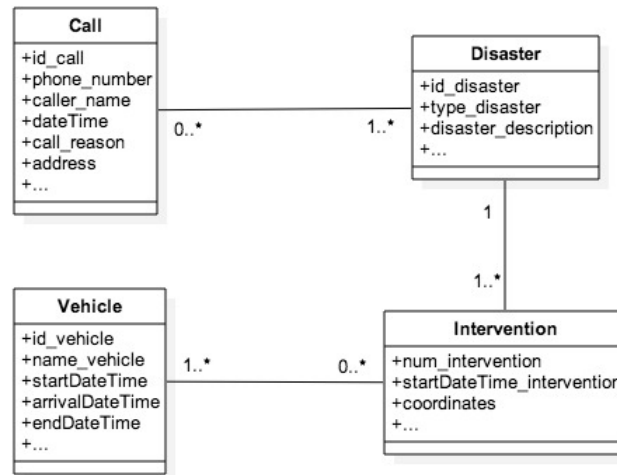

Figure 4. Class diagram of the Xynthia data set

Traces transformation

During this step, collected traces are handled in order to extract the necessary information for the process mining that follows. 3 actions are performed:

- Data filtering: experts should choose one response plan according to the current context at each crisis moment.

- Temporal ordering of filtered data for each intervention: authors need to order temporally all of a_i in A to get a temporal sequence of performed activities. Figure 5 depicts a sample of traces after performing the filtering and the ordering.

context	numInter	name	startDateTime	arrivalDateTime	endDateTime
119	4385	VLCG	2010-02-28T03:34:47	2010-02-28T03:54:47	2010-02-28T06:03:58
119	4430	VTUHR	2010-02-28T04:07:49	2010-02-28T05:08:12	2010-02-28T04:08:24
119	4464	VTU	2010-02-28T04:29:07	2010-02-28T04:52:45	2010-02-28T20:04:32
119	4464	LEPELEC	2010-02-28T04:29:29	2010-02-28T05:05:20	2010-02-28T20:23:19
119	4592	VTU	2010-02-28T07:18:37	2010-02-28T07:27:41	2010-02-28T08:53:28
119	4592	LEPELEC	2010-02-28T07:21:12	2010-02-28T07:29:15	2010-02-28T18:48:43
119	4707	VTU	2010-02-28T10:28:43	2010-02-28T10:44:50	2010-02-28T11:19:20

Figure 5. Sample of primary traces of the firefighters' intervention during Xynthia storm in France

- XES conversion: to use process mining techniques, authors need to transform all of the performed activities into eXtensible Events Stream format[3].

Figure 6 shows a part of the transformed traces that describe the performed activities for the intervention 4257. There are three activities that are executed successively: VTUHR[4], LPS[5] and VSAV[6]. Each one represents the used vehicle at some moment during Xynthia.

RESPONSE PLAN DISCOVERY IN CRISIS SITUATION

The previously obtained transformed traces base is then analysed. In this paper, the traces analysis constitutes the proposed approach and is described in the following. Our strategy to build a crisis response plan from the traces is depicted in Figure 7. We use the transformed traces base T_T obtained in the previous section. The method contains two steps: context classification and mining of the response plan.

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[3] IEEE 1849-2016 XES Standard (http://www.xes-standard.org).

[4] VTUHR (Véhicule Tout Usage Hors Route): all-purpose off-road vehicle

[5] LPS (Lot Premiers Secours): first aid bundle

[6] VSAV (Véhicule de Secours et d'Assistance aux Victimes) : victim emergency and assistance vehicle

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The first step classifies the transformed traces base T_T into different clusters. Different activities were carried out during the crisis in order to respond to one or several different contexts. Classification's purpose is to gather activities related to each specific context. As a result, we obtain the set of h clusters that will be used in the next step. Each cluster represents the chain of activities performed in the corresponding context.
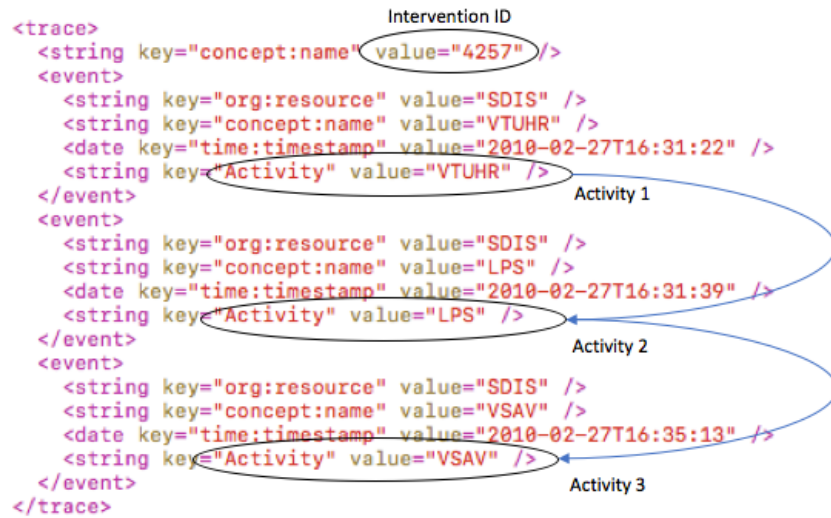

Figure 6. Example of transformed firefighters' traces during Xynthia
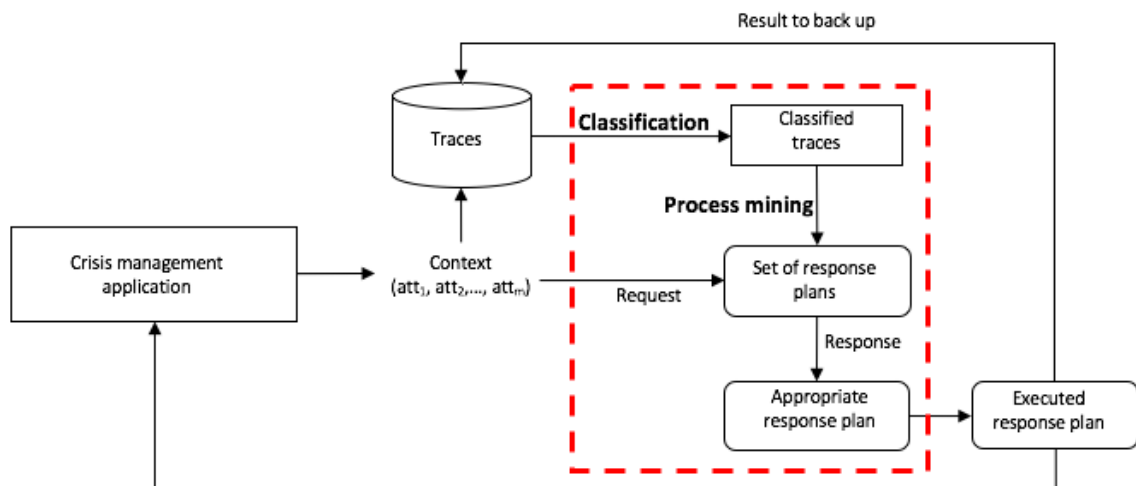
Figure 7. Process of Assisting Automatically a Resolution in Crisis Situation

The second step computes, for each cluster identified above, the response plan corresponding to its context. The discovery of the response plan is based on the chain of activities and is done by applying process mining. Among the available process mining techniques, authors have chosen the Inductive Miner (Leemans et al., 2014). At the end of this step, we discover the entire response plan that has been followed for each context in the recorded past crisis.

The two steps are detailed in the following subsections.

Context classification

The transformed traces base T_T is divided into different clusters according to different contexts distinguished by their attributes. For each context, each concerned actor creates one or several interventions that contain one or several activities to perform. The context classification works as follows. At starting point, it initializes the first record in T_T as the first cluster. Then it computes the centroid context for the first cluster, denoted by $\hat{c}_1$ and obtained by applying the formula (1) on the cluster of N records. It then computes the distance d between the context of the second record in T_T and the centroid $\hat{c}_1$ of the first cluster. The distance $d(context_i, context_k)$ between $context_i = (att^i_1, att^i_2, ..., att^i_m)$ and $context_k = (att^k_1, att^k_2, ..., att^k_m)$ is computed in (2).

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$$\hat{c}_h = \langle \frac{\sum_{p=1}^{N} att_1^p}{N}, \frac{\sum_{p=1}^{N} att_2^p}{N}, ..., \frac{\sum_{p=1}^{N} att_m^p}{N} \rangle \qquad (1)$$

$$d(context_i, \hat{c}_h) = \sqrt{\sum_{q=1}^{m} (att_q^h - att_q^i)^2} \qquad (2)$$

If the distance is less than some predefined threshold s, the second record is added to the first cluster and the value of $\hat{c}_1$ is updated. Otherwise, a new cluster is created with the second record, associated to the centroid context $\hat{c}_2$. The method iterates for all records in T_T and the distance is computed with the centroid context of each already created cluster to determine their respective clusters. At the end, we obtain the set of distinct context clusters.

Traces of the use case are classified according to different contexts by applying Algorithm 1. $C^{Charente\text{-}Maritime}$ and $C^{Deux\text{-}Sèvres}$ are respectively the set of classified contexts of Charente-Maritime and Deux-Sèvres and are the input sets for the next step, mining of the response plan.

Table 1: Context classification result

Department	Number of classified contexts
Charente-Maritime	size($C^{Charente\text{-}Maritime}$) = 25
Deux-Sèvres	size($C^{Deux\text{-}Sèvres}$) = 30

Each element in $C^{Charente\text{-}Maritime}$ and $C^{Deux\text{-}Sèvres}$ is a set of activities performed by fire-fighters in the specific context. For instance, the context type 119 found in the data set concerns 5 fire-fighter's interventions. Figure 8 gives the corresponding traces description.

Figure 8. Example of the five interventions in the context (type 119)

Mining of the response plan

To mine a response plan for each cluster, we apply on the set C above a process mining technique to extract the corresponding process model (representing the response plan) that has been applied in the previous crisis. Among existing process mining techniques, authors have chosen the Inductive Miner algorithm because:

- Crisis traces are always real-life data; they represent exactly what happened in a crisis situation. Inductive Miner algorithm is sound and adaptable for real data.

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- Inductive Miner output (process tree) can be easily converted as BPMN.

- Inductive Miner is currently one of the leading discovery approaches thanks to its flexibility, formal guarantees and scalability.

The detailed description of the Inductive Miner's advantages and algorithm is given in (van der Aalst, 2016).

IM is applied to Xynthia crisis's data set to discover a response plan according to every crisis's context. The input of this step is the obtained results of the context classification phase, C, the set of h clusters of traces. For each cluster C_i in C, IM creates a directly-follows graph $G(C_i)$ based on discovered relations between activities in all of cluster records. Then IM selects a type of cut to split $G(C_i)$ into different sub-graphs. An n-ary cut of $G(C_i)$ is a partition of $G(C_i)$ into n pairwise disjoint sets $G_1, G_2,\ldots, G_n$ with $G(C_i) = \cup_{i=1\ to\ n}\ G_i$ and $G_i \cap G_j = \varnothing$ for $i \neq j$. A cut in IM is denoted $(\varepsilon, G_1, G_2,\ldots, G_n)$ with $\varepsilon \in \{\times, \rightarrow, \wedge, \circlearrowright\}$.

The resulting set P of response plans corresponds to the known contexts. If a new crisis arises, the crisis's context(s) will be observed and compared with recorded contexts to check if there is an adequate response plan previously used in former crises that could be applied in the current crisis. Current and every referred context in P are compared using formula (1). According to this distance, we may suggest response plan from P to resolve the current crisis. It is important to note that the response plan proposed by this approach is still a suggestion for crisis's experts. They could change the response plan or adapt it in any way according to additional real-time data that they may have. Actually, each crisis situation is never really the same as some previous one and there are often unexpected events that arise during the crisis time.

Inductive Miner algorithm is now applied to extract behaviour processes for each context of our use case. The resulting process tree is given Figure 9. In the presented example, intervention 3 involves activity VTU[7] followed by activity LEPELEC[8], in the intervention 4 VTU is followed by LEPELEC and the intervention 5 involves only VTU. The null activity models the fact that sometimes VTU is followed by LEPELEC and sometimes not. This is the reason why we obtain the black rectangle in our process tree. Its formalism is: $\times$ (*VLCG, VTUHR,* $\rightarrow$ (*VTU,* $\times$ (*null, LEPELEC*))).
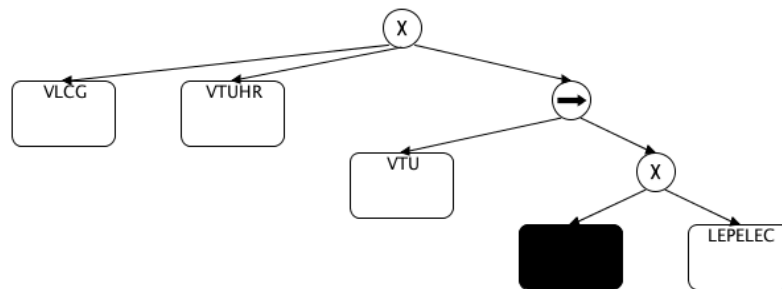

Figure 9. Process tree of the context (type 119)

Finally, the process tree is converted into BPMN. Figure 10 shows the result of this step on the example of Figure 8 and represents the response plan for the context 119. It summarizes what was done by the fire-fighters to face the context type 119 during the Xynthia crisis. The resulting plan becomes a referenced help for the fire-fighters for the next crisis's context of type 119.

The presented example is based on 4 traces, so it produces a relatively simple process tree and response plan. However, with more data more complex process models may be obtained. For instance, the context type 61 that contains 14 traces is modelled by the response plan depicted in Figure 11.

EVALUATION

Authors have assessed the performance of the proposed approach by different tests to evaluate the quality of discovered processes (response plans). Authors focused on the four quality dimensions generally used to evaluate an obtained process model that are:

- *Fitness*: this measure assesses the extent to which the obtained process model could reproduce all the available traces. To measure the fitness, we can replay the recorded traces on the obtained process model to identify mismatches between them. The formula to compute this quality can be found in (van der Aalst, 2016) and (Buijs et al., 2012).

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[7] VTU (Véhicule Tout Usage) : all-purpose vehicle
[8] LEPELEC (Lot Épuisement Électrique) : electrical exhaustion bundle

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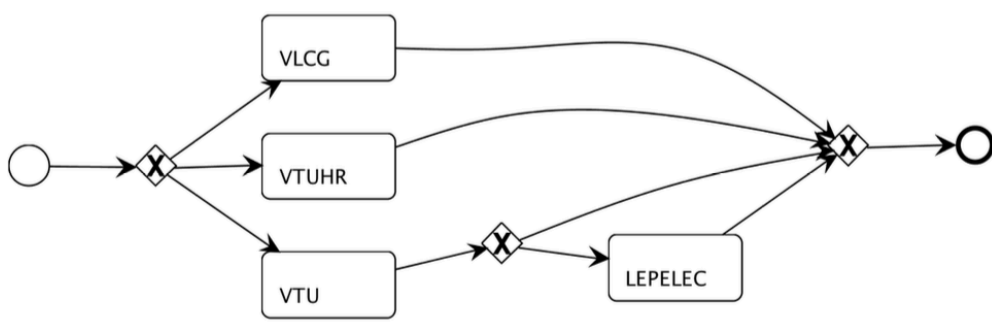
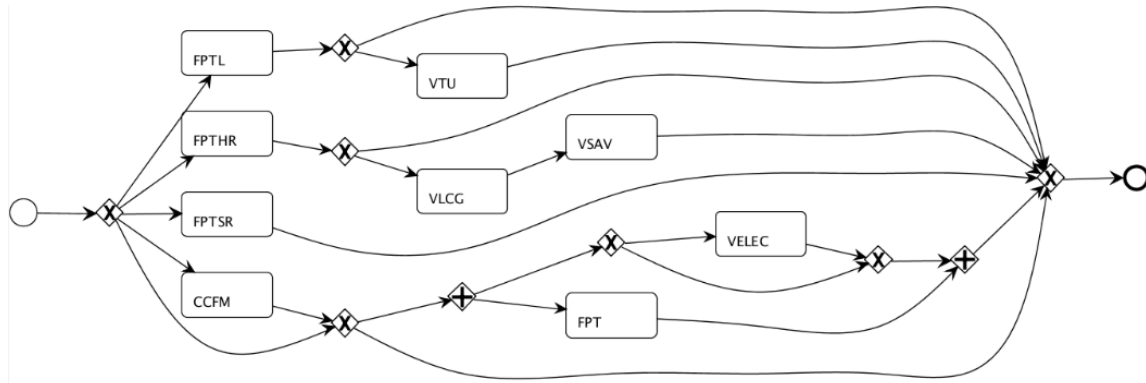**Figure 10. Response plan (BPMN) of context (type 119)**

Figure 11. Response plan (BPMN) of context (type 61)

- *Simplicity*: this value represents the structural extent of the process model. This aspect is intuitive and still discussed in the community. The simplicity evaluation depends on the users' point of view. There exist a variety of methods to compute the process model simplicity. We have chosen the structural characteristic to evaluate model's simplicity (Rozinat & van der Aalst, 2008).

- *Precision*: a model is precise if it does not allow too many different traces (Buijs et al., 2012). In other words, precision describes the fraction of the activities allowed by the model but not seen in the traces.

- *Generalization*: this kind of process quality quantifies the extent to which the obtained process model will be able to reproduce the future traces of the process (Buijs et al., 2012). In different terms, the model should generalize and not restrict to the available sequence of activities seen in the already collected traces (van der Aalst, 2016).

The value of these metrics ranges from 0 to 1, close to 1 the quality is more satisfied. It is very difficult to find a balance among the quality dimensions above. For example, precision and generalization cannot be satisfied simultaneously. Four metrics were computed on the obtained process models in order to assess these qualities. However, we especially would like to insist on the fitness quality. Our main research idea is to extract the response plan from the available traces. Authors need a response plan that should represent all of the past activities. The fitness dimension assesses this property.

Figure 12 and Figure 13 are respectively the obtained results on the four quality dimensions above for French departments Charente-Maritime and Deux-Sèvres. Authors focus mainly on the capacity of modelling process based on available traces. If a process obtained by the method is able to replay all the traces, we conclude that the mined process fits well with the past activities (the fitness metric is represented by the blue column in and Figure 13). Authors emphasize that on the two obtained results, the value of fitness is always satisfied (equal to 1). This result illustrates that the process model discovered by the proposed method synthesizes all the processes performed in the past and that the obtained response plan accurately represents what fire-fighters do in previous different crisis's contexts.

The three remained qualities also impact the obtained results in the process mining domain. Based on the number of traces in each cluster, authors could discover a simple or complex process. When the number of traces increases (for instance, context type 47, 22, 118 of the Charente-Maritime and 34, 52, 2 of the Deux-Sèvres), the resulting process model may be very complex (the value of simplicity is always under 0.5). Nevertheless, the more complex the process is, the more its generalization quality deteriorates (the value of generalization is always over 0.5 for contexts mentioned above). Furthermore, the experimentation shows that it is very rare to get

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a process model with both high precision and high generalization qualities.
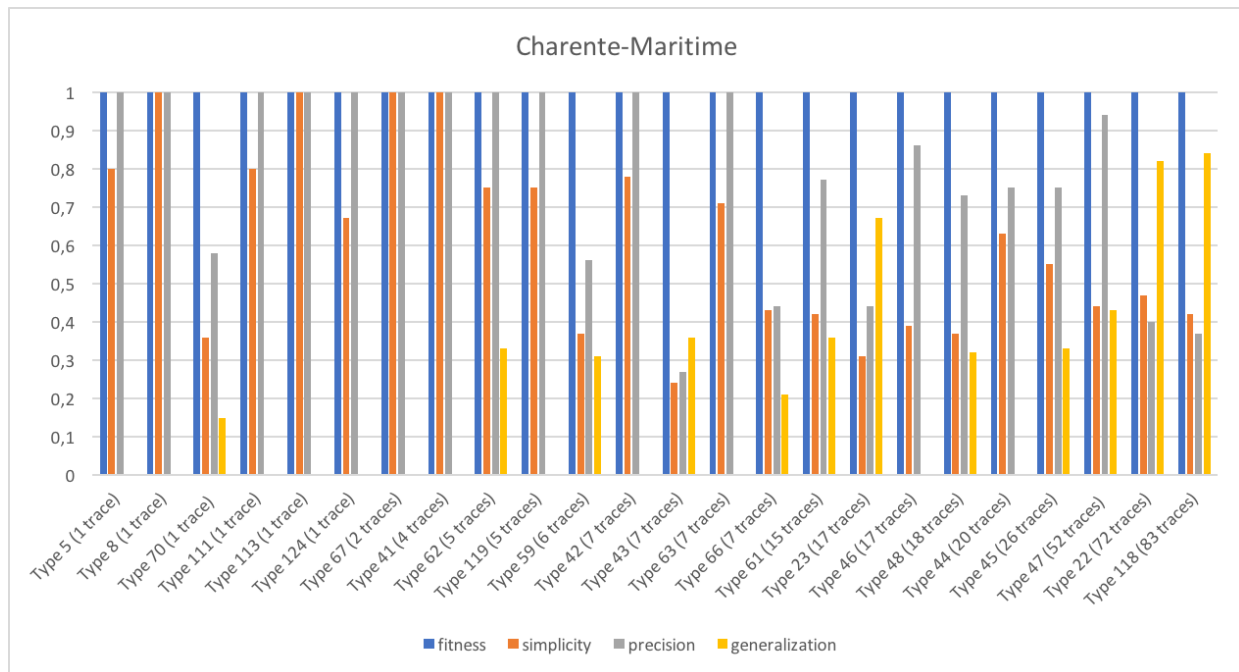

Figure 12. Four quality dimensions on the obtained results (Charente-Maritime department)
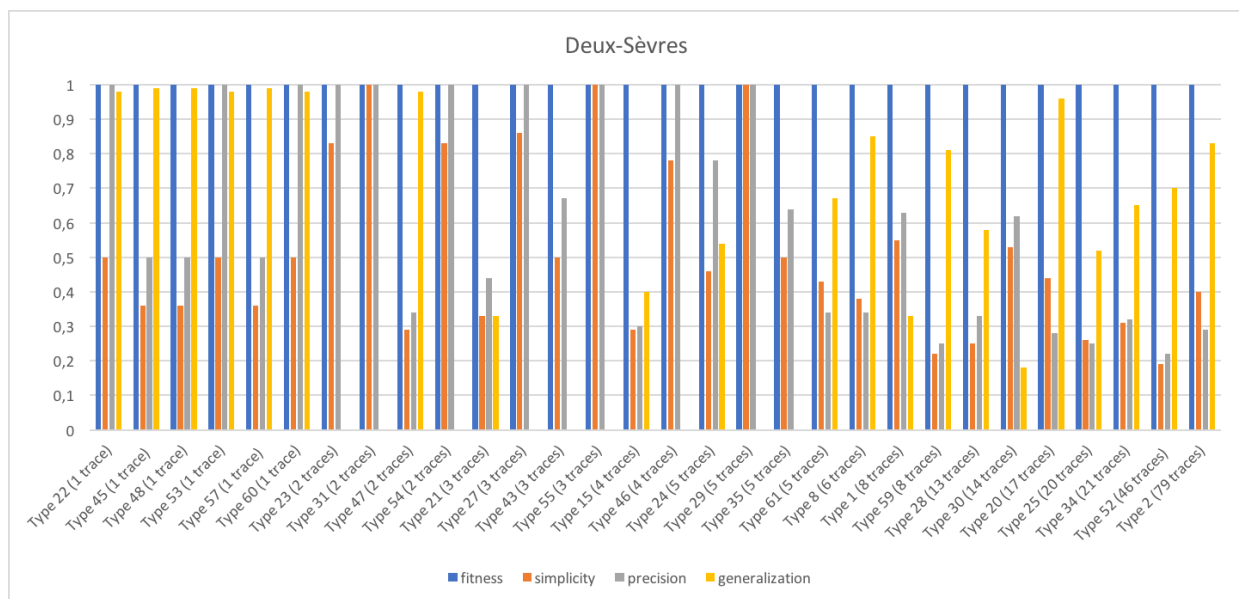

Figure 13. Four quality dimensions on the obtained result (Deux-Sèvres department)

To summarize, the obtained results illustrate that the proposed approach could assist experts during crisis situation. By integrating the context classification in the proposed approach, authors could classify different performed activities for every different context in crisis. By applying Inductive Miner, authors proved its efficiency on modelling a response plan (process) based on activities classified traces.

LIMITATIONS

The approach has some limitations. It is efficient only if enough traces are available. If there is not enough data, we cannot obtain a general process model, the quantity of the available traces directly influences the relevance of the resulting response plan. It is the reason why an expert is always required to assist the response plan validation throughout the time of crisis. In case of non-relevance, expert could change the suggested response plan and adapt it to the current crisis situation.

Another key issue of the proposed method concerns the context classification. This step computes a distance

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between a current context vector and each centroid context vector. The value for each attribute in this vector should be numerical in order to apply the Euclidean distance. However, to describe a context of crisis situations, we may have a vector that contains different types of attributes that could be discrete or continue. The used distance formula may not be suitable. In terms of semantics, this type of distance does not take into account the semantic difference between two contexts. The distance computation should be adjusted to overcome this limit. Moreover, each attribute in the context vector has its different relative importance. An attribute may be considered as important in some crisis, but it may be not important in another one. Therefore, multi-criteria weighting (Ho et al., 2014) should be performed to estimate the relative importance between considered attributes in the context vector for each type of crisis in order to overcome this issue.

CONCLUSION

This paper presents a strategy for assisting experts to make a response plan for a crisis situation. The approach is based on the analysis of traces collected during previous execution processes in past crises. A Trace-Based System was adapted to crisis context in order to collect and transform the recorded information. The proposed approach is applied to extract the response plan for each identified crisis context. The approach first classifies the context and the performed activities in past experiences into different sets of activities according to different discovered contexts. Then Inductive Miner, a process mining technique, is used to discover the process model based on the set of previous activities. The resulting process represents the response plan that is suggested as a reference aid for experts to resolve the current crisis.

The proposed approach answers the problem stated at the beginning of this paper: how to automatically discover a response plan in crisis situations? In terms of methodology, we have described in detail how the proposed approach strategy works. Besides, we applied the approach on a case study of fire-fighter's interventions in French departments Charente-Maritime and Deux-Sèvres during Xynthia windstorm crisis in 2010 to assess approach's efficiency.

As perspectives to the presented work, authors intend to overcome the mentioned limitations to get a suitable strategy to different crisis contexts. On one hand, the presented methodology will be included in a crisis management environment under development. This environment aims to provide to experts and to different actors a set of centralized data collection, data visualization and communication tools to deal with crisis situation. On the other hand, we seek to generalize and improve the classification procedure especially by defining a more general and more precise distance computing function including multi-criteria attributes weighting. Furthermore, authors underline the importance of experts' role in crisis situation. Even though, the number of traces will automatically increase over time since the trace-based system of the crisis management environment will accumulate crisis data when new crises arise, authors propose to combine the response plan obtained from the proposed approach with experts' skills and experience. Since the expert remains the qualified decision taker for crisis management.

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