Decision Support System for infrastructure network disruption management

Daouda KAMISSOKO, Pascale ZARATÉ
IRIT / SMAC
118 route de Narbonne, F-31062 Toulouse Cedex 9, France
daouda.kamissoko@irit.fr, pascale.zarate@irit.fr
web-page: http://www.irit.fr/-SMAC-team-?lang=en

François PÉRÈS
ENIT / SDC
47 Avenue d'Azereix 65000 Tarbes, France
françois.peres@enit.org
web-page: http://www.enit.fr/fr/recherche/le-laboratoire-genie-de-production-1.html

ABSTRACT
This paper deals with the development of a Decision Support System (DSS). The DSS (VESTA) aims to analyse the vulnerability of interdependent critical infrastructures in the context of natural disaster. The issues in this particular decision context are identified. Characteristics to be respected and the software architecture are presented. Various modules components of the system are described. The methodology presents different granularity of the implementation and the use of the DSS.
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Introduction

Disasters have always been societies destabilization source since the beginning of the human societies. In the past, they were attributed to divine wrath sign. Afterward, we begin to understand their manifestations. Actual knowledge allows disaster description through models more or less established. But it is still hard to eliminate causes even if those are identified. The last line of defence is prevention or coping with them.

Disaster affects many stakes including infrastructure network. Through interdependence, a failure of one component might lead to those of the others by a cascading failure. This situation should lead to a complex crisis.

One of the challenges in the management of the crisis is the responsiveness of decision makers. The use of a Decision Support System seems primordial in such situation. Indeed, every second counts, therefore decisions must be taken quickly. Using simulation seems essential then.

The objective of this paper is to present a Decision Support System for infrastructure network disruption in a context of natural disaster. First issues of the DSS are presented. Features to overcome these issues are enumerated. Next the used architecture is described. Last the resulting software is presented.

Issues

Decision is one of human being main cognitive activities. In fact, man is a being who doubts. Through the doubt mechanism, it is in constant reflection in every decision process. This situation is further emphasised whenever more than one choice is available to him.

Each decision is taken in a specific context. In most cases, decision-makers emotional states are stables, consequences are acceptable and do not require any special justification. Conversely, there are situations where consequences may be unacceptable. For some of them, even if consequences are acceptable, they require a justification. Natural disasters are especially suitable to such situations.

Natural disaster decision context varies greatly according to the decision-makers emotional states, the consequences extend, the need of justification, and the decision subject complexity.

Thus, in natural disaster situations, the need of being helped seems obvious for decision making. Using computer software (Decision Support System) is therefore valuable. In fact such system provide decision making support for managers at all levels[1].

The next section present definitions of such system and some of their features.

Definitions and Features

Decision Support System is computer-based system for decision support [2]. It is defined as an integration of computer hardware and software that is designed to complement the cognitive processes of humans in their decision making [3]. The developed system in this paper is called VESTA.

DSS features as those of classical software depend on the use. They were described by Sprague and Carlson through the ROMC approach [4]: Representations, Operations, Memory Aids, Control Mechanisms. With regard to decision support systems in a disaster management, they might be flexible, adaptive, responsive, interactive [2], progressive and controllable [3]. To these features, we have identified several others: response time (rapidity), geographical distribution, views integration, use simplicity, portability, ergonomic, adaptability and efficiency.

The next section presents the architecture that suits these features.

Architecture

The Architecture adopted is composed of three parts those presented by Sprague [1]. It is composed of: Human Computer Interface, Data Base, and a Model Base. William A. Wallace in [3] added to these parts a data analysis capability. In our approach this module is managed by the Data Base Management System. In some situation like that related to territorial management, a spatial DSS can be doted to prominent spatial components [5].

Data Base is doted of data analysis capability performed by a Data Base Management System (DBMS). The Model Base is related to a normative model implemented in a Model Based Management System (MDBS). The Human Computer Interface is related to a Dialogue Management System.

The next section presents these components.

The Human Computer Interface

The Human Computer Interface represents all windows accessible to users. The nine windows of the application have been prototyped with Balsamiq [6]. At the encoding time, the GUI was drawn by WindowsBuilder - an Eclipse IDE plug-in [7]. The dialogue management system related to the Human Computer Interface is implemented through Java Classes.

Figure 1: Human Computer Interface of VESTA

A feared event like a flood can be aggravated or mitigated by some natural or artificial factor (like a dam). Figure 1 presents the HCI of these with their parameters.

Database

Decisions emerge from the processing performed on data. Data are located in a database. The Unified Modelling Language (UML) is used for the data description.
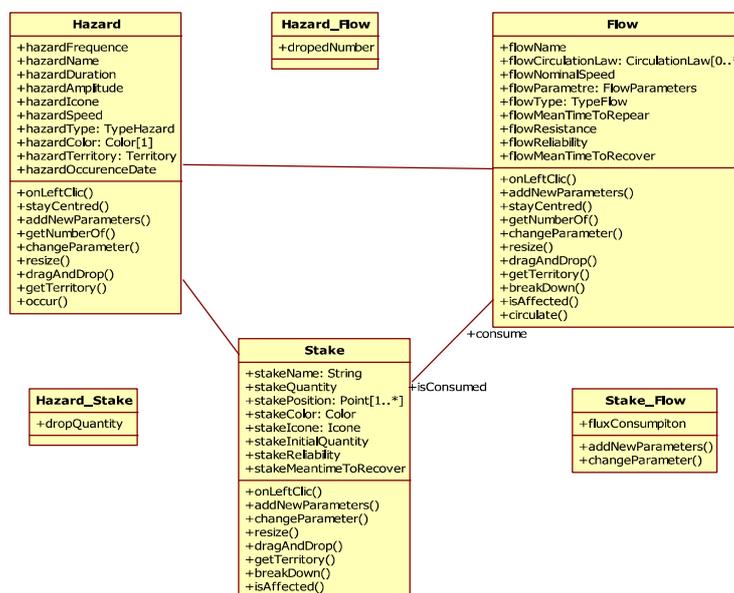

Figure 2:Class diagram with StarUML [8]

Figure 2 represents a part of the data model. At its occurrence, a feared event (Hazard) affects circulating flows in the network and stake. The real data base implements 30 classes and 12 relations.

Model base

The model base is managed by a Model Base Management System (MBMS). The functional and dynamic modelling of MBMS are performed through the object approach. This approach included actors identification, building the static context diagram, determining relationship between use cases, identifying use cases for human actors, establishment of sequence diagram and activity diagrams.

Several kinds of actors are identified: International, National, Regional, Infrastructure Manager, Local Operator, Emergency, Citizen and the Analyst. For each of them several use cases are defined. In a general way, we defined 14 scenarios. The example in Figure 3 shows that a local actor can determine among others critical components, effective actions, feared events etc.
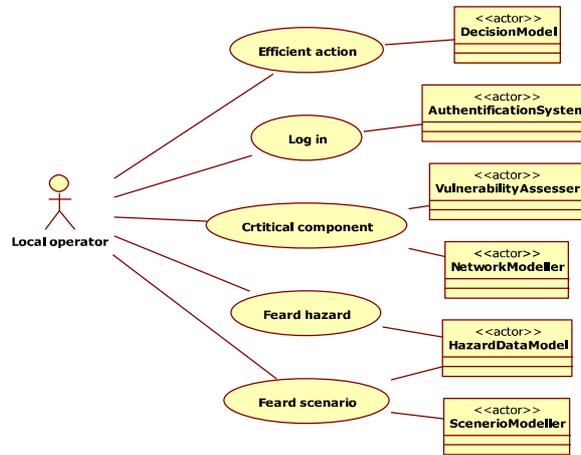

Figure 3: Use case for local operator

Use cases in Figure 3 are based on the vulnerability model presented in the next section.

Vulnerability model

Vulnerability is "a stake's inability to resist the hazard's occurrence and to recover effectively it nominal functioning for a given period of time" [9]. Vulnerability depends on the hazard and the system state, it is given by:

$$V = P(Hazard) \times (1 - \prod_{n=1}^{N}(1 - \vartheta_n)) \qquad (1)$$

ϑ_n is the intrinsic vulnerability of one component. It is given by:

$$\vartheta_n = (1 - R_b)(1 - R_s) \qquad (2)$$

R_b is defined as the robustness and R_s the resilience. The reader may refer Kamissoko et al (2013) for more information [10].

Coding

We have chosen Java as language development because of its portability. In addition, Java is free and can run on different computers such as PC, MAC without any change.

The system is fully implemented by using swing as an API for graphics and JUNG to represent the network [11].

DSS functionalities

The Decision Support System for Interdependent Network Vulnerability Analysis realized in this study contains an ergonomic graphical user interface which allows the user to choose different possibilities depending on his rights. The main developed functionalities are the following: Network modelling, Interdependence modelling vulnerability assessment, efficient actions determining, critical element identification (network component, stake, flow, territory, feared event).

Network drawing

The software enables the user to import a map as a picture or to select an area from a real map (using Google maps for example). Then, specify the boundaries of the geographic area to work on. If the user doesn't find a map, the software offers the possibility to draw the territory and represent it by its boundaries on the zone. Territories are resizable (zoom, changing the boundaries, extension...)
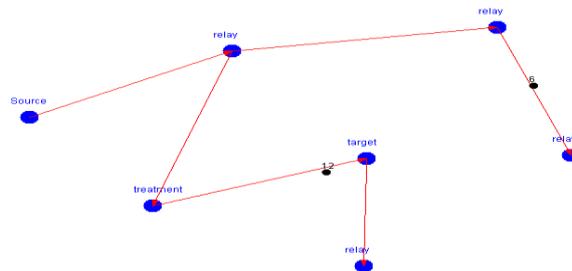

Figure 4: Network drawing

Another possibility is given to the user allowing him to draw the network by a drag and drop of the network's components on the territory that he has already imported or drawn (Node, edge, Hazard, factor, issue, etc.). The user can specify the settings for each item in a separate window.

Figure 5: Node Parameter setting

Simulation

The system is able to calculate the vulnerability of a country or a network. The country must first of all be modelled by the analyst. When the country is modelled, new parameters as feared event and stake have to be estimated and the system can then simulate the vulnerability. For elements (network, relationship, territory, component, stake, stream, factor, hazard Scenario), the application calculates the vulnerability of each element and shows the result in the form of Pareto chart. This chart allows element classification according to their induced part in the global vulnerability. The developed system is for the moment a prototype and must be improved.

Conclusion

Natural disasters affecting infrastructure networks are destabilizing events for the society. In such crisis management the use of computer systems is required. Decision Support System for crisis management should be effective and efficient then.

The objective of this paper was to present a vulnerability model-based Decision Support System. Every component of the architecture is described. The obtained DSS allows an estimation of infrastructure network vulnerability taking into account interdependences. Thus it is possible to deduce among others vulnerable areas, critical components and the most threatened stakes. As perspective we hope to deploy this application on the internet and on mobile devices (smartphone, tablet).

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