A Conceptual Architecture to handle the influx of information in Emergency Situations

Bruno S. Nascimento
Programa de Pós-Graduação em Informática
Departamento de Ciência da Computação
Universidade Federal do Rio de Janeiro, Brasil
bruno.nascimento@ppgi.ufrj.br

Adriana S. Vivacqua
Programa de Pós-Graduação em Informática
Departamento de Ciência da Computação
Universidade Federal do Rio de Janeiro, Brasil
avivacqua@dcc.ufrj.br

Marcos R. S. Borges
Programa de Pós-Graduação em Informática
Departamento de Ciência da Computação
Universidade Federal do Rio de Janeiro, Brasil
mborges@nce.ufrj.br

ABSTRACT

Emergency situations are characterized by their complexity and the heterogeneity of the available information. Emergency managers are frequently confronted with redundant or irrelevant information, causing the problem of information overload. Evidence of this problem was identified in an exploratory survey conducted in the Center for Integrated Command and Control of Rio de Janeiro (CICC-RJ). In this paper, we present a conceptual architecture that allows a user to handle this influx of information. From a set of available data, a manager can select those of interest, which can then be transformed and mapped into one or more views, and organized in a dashboard. The whole process is interactive, allowing the manager to redefine his/her dashboard as needed. In addition, we provide collaborative mechanisms, given that, at times, it is not possible for a single user to handle such large datasets alone.

Keywords

Emergency, Heterogeneous Information Sources, Information Integration, Collaboration, Visualization of Information, Dashboards.

INTRODUCTION

Information management in emergencies is experiencing a revolution in terms of available information sources. In many scenarios, emergency managers can access large and diverse databases and easily obtain a large amount of information. However, part of this information may be irrelevant, which causes information overload (Comes et al., 2012).

The problem of information overload refers to the danger of becoming lost in data, which may be irrelevant to performing a task, or may have been processed or presented in inappropriate ways (Keim et al., 2008). In emergency situations, this problem should be avoided, but without restricting access to information (Engelbrecht et al., 2011).

Emergency managers are confronted with redundant or irrelevant information causing the problem of information overload. Even when managers have a consolidated view of information, most solutions available provide little or no customization in its selection and visualization. Thus, new information or visualization needs are usually not taken into account. For example, different users may have different visualization preferences, such as color, shape and interaction styles. Even for the same person, information and visualization requirements can change from time to time as he or she becomes more familiar with the problem domain and the visualization system in use (Bai et al., 2012).

The aforementioned problem has been evidenced in a real scenarios as C2. Since 2014 we have been conducting an exploratory study at the Integrated Command and Control Center of Rio de Janeiro (CICC-RJ, Portuguese acronym for Centro Integrado de Comando e Controle do Rio de Janeiro). In this study, we evidence that emergency managers are often overwhelmed with reports and data provided by distinct information systems that compete for their attention.

To overcome information overload, information systems must be designed to provide the right information at the right time, and present it in an appropriate way to the right person (Fischer, 2012). This work presents a conceptual architecture that allows emergency managers to select only the information of interest and how to present it, given their context. Collaborative characteristics must also be provided, because there are times when it is not possible for a manager to make decisions alone. Thus, we seek to transcend the traditional visualization systems, going from a monolithic structure - with a single user interacting - to a structure that supports collaboration. Through a transition between models, managers can select information from raw data sources, conduct analytical operations and compose the appropriate visual representations for each type of information. This process allows managers to define their own workspace, represented by a dashboard. The whole process is interactive, allowing managers to redefine the dashboard as needed.

Although there are other initiatives that address this problem in emergency situations (such as Wolbers et *al.* (2013), Zagorecki et al. (2012), Ibarra *et al.* (2012), Engelbrecht et al. (2011), Canós et al. (2010) and Döweling, Probst, Ziegert, & Manske (2009)), the conceptual architecture proposed (at first time) aims to meet needs and requirements for selection and visualization of information to CICC-RJ managers.

This paper is structured as follows: Section 2 describes the exploratory study and requirements for our proposal; Section 3 details the conceptual architecture. Section 4 lists technical challenges for implementation. The last sections show current efforts and final considerations.

EXPLORATORY STUDY

CICC-RJ is the main element in the coordination of the actions of security for major events in the state of Rio de Janeiro. It integrates public service agencies and monitors and supports security, safety actions taken by federal, state and local agencies, and responds to emergency calls (Filho et al., 2014). CICC-RJ is a new C2 Center based on the C2 Model (Builder et al., 1999).

The exploratory study involved several steps: on-site observation, documentary research and semi-structured interviews. Sections 2.1, 2.2 e 2.3 describe these steps in detail. In Section 2.4, based on the findings of the exploratory study, we list the requirements we consider essential for our proposal.

[OB] On-site Observation

During observations, our main concern was not interfering with the activities carried out by emergency managers. During this step, we followed actions during routine situations and preparation for monitoring emergencies with high social impact, such as large events, natural disasters and crowded social events. Table 1 shows some of the findings of this observation.

Table 1. Findings of on-site observation

Code	*Findings*
OB1	Integration of different agencies in the same place does not mean completely shared databases. This point is critical because there are several questions about the preservation of confidential information.
OB2	Despite the name "CICC" suggesting integration, there are few tools that enable the integration of information between agencies.

OB3	At times, emergency managers receive more information than they can absorb, because they do not have the capacity and resources available to process them.
OB4	Even with all the technological apparatus available, the monitoring of information depends on human mediators and their interpretative capacity.
OB5	Existing visualization tools have few mechanisms for personalization.
OB6	During an emergency, decisions must be made quickly using the best available information.
OB7	The information is not shared in a structured way among agencies. Some of the agencies needed to resolve an incident sometimes fail to realize that there is an ongoing problem.
OB8	In some situations, the ability to collaborate on the same screen is required. In other situations, managers need to exchange views between each other.

[DR] Documentary Research

Documentary research was conducted in order to find evidence about the procedures adopted by the CICC-RJ: C2 structure, conflict resolution, agencies operation limits, schedule work, communication (ways, means, procedures, etc.), infrastructure, etc. The documental research allowed us to establish the necessary theoretical basis for understanding the domain and to help the interview preparation.

[SI] Semi-structured Interviews

Semi-structured interviews were conducted with three representative of CICC-RJ Coordination. The mean duration of the interviews was approximately 70 minutes. The purpose of the interviews was to understand the structure of the CICC, decision-making process, visualization systems available and challenges they face. The interview questions were previously developed by the research team aiming to elicit requirements. Table 2 lists some difficulties related to the problem of information overload collected from the interviews.

Table2. Findings in the interviews

Code	***Findings***
SI1	There are difficulties in deciding what should receive attention and get key information of interest according to the context.
SI2	Failure to ability or lack of resources to add value to information that may be lost or unrecognized.
SI3	Information overload increases when reports are poorly designed with respect to how information is presented.

Essential Requirements

To further develop our proposal, we elicited a set of essential requirements. We grouped these requirements into aspects to simplify the construction of our proposal. Table 3 presents these requirements and their relationship with the findings of the steps of the exploratory study already described in Tables 1 and 2.

Table 3. Essential Requirements

Aspects	***Requirements***	***Findings***
Data integration	The solution should enable the integration of dynamic data, heterogeneous, and from different sources, such as traffic reports, weather reports, flood warnings, local	OB1, OB2.

	cameras, sensors or any other available resource. It is essential to control and organize the information. It is necessary to create a common way for collecting and processing of data, as well as aggregation of new sources. The solution should provide criteria for classifying the quality of information.	
User context	The solution must take into account the user's context through customization of selection and visualization functions. The solution should enable the creation of new information (through analytical operations) from existing data sources.	*OB3, SI1, SI2.*
Visualization and user interaction	The solution should enable the exchange of views according to the context, which is defined by the manager. The solution should enable the visualization of different levels of detail of the information.	*OB4, OB5, OB6, SI3.*
Collaboration	The solution should enable collaboration through exchange of information and views. In addition to enabling shared control in some situations.	*OB7, OB8.*

CONCEPTUAL ARCHITECTURE

The proposed architecture enables each manager to select and view information of interest according to its context and also provides mechanisms for collaboration. Our conceptual architecture starts with the generation of domain data and ends with the presentation of one or more visualizations on a dashboard. Dashboards can support a wide range of needs for monitoring, covering all tasks that benefit from an immediate overview of what is happening, and reduce information overload (Few, 2013).

The collaborative visualization model and the essential requirements elicited in the exploratory study formed the basis for our architecture. Like to the proposed of Wood *et al.* (Wood et al., 1997) our approach includes a visualization pipeline for each collaborator considering the performance of many independent participants. Each user can exchange data with others at arbitrary points of the pipeline, sending and receiving data and creating a shared workspace. Additionally, each manager has the option of joint control, where the definition of parameters can be controlled locally or externally by a collaborator.

Figure 1 shows three models and their steps going from raw data left to the visual representation right. Each model is presented below.

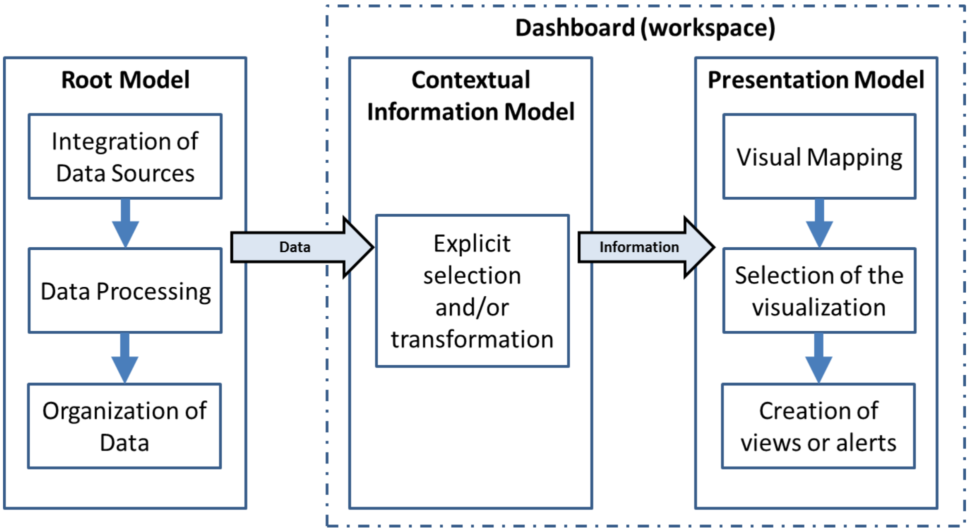

Figure 1. Conceptual Architecture Proposed

Root Model

The Root Model represents all data available in the domain in its raw state. Generally, these data are part of the knowledge bases of various computer systems or inputed by the user.

The set of raw data collected can be fully dynamic, heterogeneous and from different sources. This data can contain dates, measurements, codes, descriptions, images, videos, and more. Different entities, attributes, and relationships are represented in this data set. Due to the nature of the data, it is necessary to perform the following steps: "Integration of Data Sources", "Data Processing" and "Organization of Data", so information may be obtained by a query.

Contextual Information Model

The Contextual Information Model contains information from the root model. In this model, raw data is organized for a particular purpose, using a hierarchy to enable generation of knowledge.

The information that makes up this model can be obtained through the step "Explicit selection and/or transformation". This step is performed by the manager, who selects the information of interest according to his context. Context is represented by the task, availability of data, and individual preferences. The transition from the Root Model to the Contextual Information Model provides the flexibility to adapt their workspace to information needs. This is useful because managers are only interested in information that has value in their current context.

Regarding methods for transformations, they allow the manager to operate directly on the attributes and data, detailed below.

- Attribute filters: removes attributes judged irrelevant to the context. This filter allows the manager to disable attributes by some condition or by explicit exclusion.
- Data cleaning: removes attributes considered irrelevant to the context. Strategies for cleaning should remove records that do not meet any criteria, such as: ignore records, manually complete the missing values, substitute a global constant, or use average to fill in the missing values;
- Data integration: integrates data stored in different sources or bases;
- Generation of derived attributes: generates new relevant attributes from the raw data the manager. Derived attributes can be obtained from several operations, such as mathematical operations (eg. multiplication, addition, etc.), summarizations, changes of types (eg. numeric type to alphanumeric numeric type), logical combination of two or more raw data: IF ... THEN;

Presentation Model

The Presentation Model represents how information are presented to the manager. When a manager visualizes an information graphically, he handles it in a more automatic, more superficial, parallel (in order to obtain various information simultaneously) and faster way, thus reducing the cognitive effort required to process information (Ware, 2004). Our model is divided into steps as: “Visual Mapping”, “Selection of the visualization” and “Creation of views or alerts”.

The step of "Visual Mapping" aims to map the information to a type of visualization. These types can range from traditional graphics (points, bars, circular and histograms), tables, elaborate forms (with the use of colors and geometric symbols), real images (pictures or videos) or mappings (of an object or physical space) to more complex representations by use of diagrams (trees, graphs and networks) or visual metaphors, referring to abstract concepts and relationships.

The “Visual Mapping” must be done entirely by the application. The relationship of information for a type of visualization is 1 ... n. One element of information can have one or more associated views. This information can be mapped to different types of visualization such as bar charts, pie charts, etc.

The next step is "Selection of the Visualization", where the manager defines the visualization that will make up the dashboard. Given that, in the previous step, each information element was mapped to one or more types of visualization, he can choose which view is most appropriate for his context, defining their workspace.

Finally, the step of “Creation of views or alerts” allows managers to make changes on the views, allowing them to extract more information from a visualization than would be possible with a static representation. For example, the manager can change the zoom to a more detailed level. In addition, he/she can also create alerts to help identify contextual changes that need attention.

TECHNICAL CHALLENGES FOR IMPLEMENTATION

This section summarizes a number of immediate challenges for implementation of our proposal.

- **Infrastructure:** Managing large amounts of data for visualization requires special data structures and mechanisms. Thus, the software infrastructure must be built using well understood technologies such as: database and software components.
- **Ease of use:** Emergencies are complex and exceptional events, therefore familiarity with a specialized user interface which needs thorough training cannot be assumed.
- **Integrated analysis:** In emergencies, data from multiple, heterogeneous sources need to be integrated and processed jointly. In these cases, the software system should be able to integrate a range of different types of data sources independently of data schema.
- **Scalability:** The amount of data to be displayed is huge and therefore can overcome the display capability in several orders of magnitude. Thus, the software system should have the ability to effectively exhibit large data sets in terms of the number of individual data elements or in terms of their dimensions. To overcome this challenge, the solution must have techniques for data reduction, such as sampling, filtering, grouping, etc.
- **Real-time visualization:** As the data is being produced in real time they should be treated and displayed. However, it is not easy to design and develop this kind of view.
- **Errors and uncertainty:** Data are often uncertain and imprecise. In addition, uncertainty can arise at any stage of visualization process.

FINAL CONSIDERATIONS

In this paper, we presented an exploratory study conducted in the Integrated Command and Control Center of Rio de Janeiro (CICC-RJ). We found evidence of information overload and we verified that the success of managers depends on having the right information available, at the right time, presented in an appropriate way.

The study led to the elicitation of requirements and assessment of theories or existing concepts that could be applied to the problem, or if new approaches would need to be developed. Based on this study, a conceptual architecture was proposed, that allows a manager to select and view information of interest according to his/her context and provides mechanisms for collaboration.

Our architecture starts with the generation of domain data and ends with the presentation of one or more visualization on a dashboard. Through a transition between models, managers can select information from raw data sources coming from the domain, conduct some analytical operations and end with the appropriate visual representations for each type of information. The whole process is interactive, allowing the manager to redefine his/her dashboard as needed.

We are continuing this work by implementing this architecture in a computational system (Figure 2). We expect the solution will help managers to identify information of interest or requiring immediate attention and thus reduce information overload. Furthermore, it is important to emphasize that the use of collaborative mechanisms is each manager's decision. He/she decides when and what to share, and even those who exercise local control of a data set (or views).

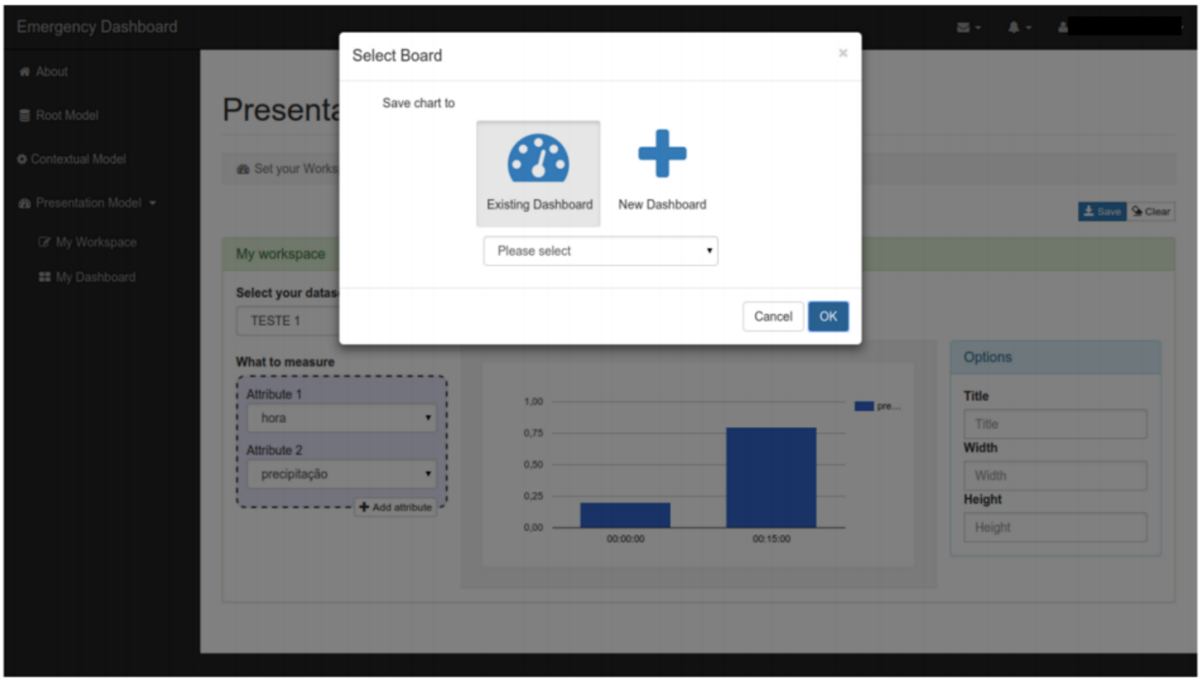

Figure 2. Select Board of Presentation Model

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