Dynamic and Context Aware Reporting of Observations from the Field for Situation Assessment in Crisis Situation: An Integrated System for Information-Gathering and Sense-Making

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Abstract. An efficient process for gathering data from the field is crucial in managing crisis scenarios. In this paper we present a concept system for crisis management with focus on how observations from the field are reported using hand held devices and integrated into a common operational picture. The application used for reporting situation from the field adapts to the current situation in real time by adding and hiding input field based on what the user is reporting. Moreover, the user interface will also adapt to external information request. This is realized by utilizing risk event models for real time risk assessment and identification of areas where information is lacking which can generate new requests for information.

Keywords: Crisis management · Semantic techniques · Dynamic forms · Risk alert · Information management · Situation assessment · Continuous and real-time risk assessment

1 Introduction

In big scale disasters such as tsunami and earthquakes the sheer information to process to achieve an overview of the situation is a daunting, and sometimes an overwhelming task. An efficient information management process is crucial in a crisis situation in order to understand and assess the situation in terms of damages and needs, both present and future. Situation awareness is achieved by collecting data from sources in the field and combining this information with background data. Many systems exist today that focus on the geospatial aspect which is realized by plotting data on a map. In order to speed up the process of gathering data from the field, responders have started to use hand held devices such as tablets which has many benefits. The data reported is in digital format which makes it easier to process and if the telecommunication infrastructure is intact, the information can also be transmitted to stakeholders immediately. Unfortunately, most solutions do not deal with the problem of filtering data and information very well: the operator gets an unfiltered view which contains both the relevant and the irrelevant information to the operational picture. Furthermore, information gaps might not be easy to spot

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because the amount of data might be overwhelming, especially in a larger operation. This flood of data partly comes from that the information gathered from the field. The data is often in the format of free text or predefined forms covering different event types. Structured data can be analyzed with a lesser amount of processing which makes it usable with lesser delay. Therefore it is common to use pre-defined static forms, tailor-made for different reporting situations, in order to make sure that no information piece is forgotten also ensures that data is structured. However, this approach is not always the best way to gather information. In this paper a concept is presented which deals with the filtering of data and how dynamic forms can be generated to help with the data gathering.

2 Related Work

There are several tools available for gathering data by the use of mobile devices available today. Many of these support basic features such as creating forms and questionnaires that can be answered using a mobile device. Other commonly supported features are data analysis, data aggregation and plotting the collected data on a map. Some systems support a two way communication where data can be requested from the mobile device or pushed to it.

In systems like KoBo Toolbox [1] and EPIcollect [2] the questionnaires allows for logic that makes the form more dynamic in terms of hiding and adding questions based what has been entered so far. In GDACSMobile [3], categories are used to specify the context of a situation report. The categories are linked to templates that contains specific assessment question. When the user selects a category for the situation report, he/she will be asked to answer additional question based on the template. The templates are flexible and can be re-configured to match the specific needs as the situation evolves.

3 Concept Model

In the following sections the concept model is introduces. In Sect. 3.1 the main objectives are defined. Section 3.2 contains the overview of the concept, Sect. 3.3 contains the risk model logic, Sect. 3.4 the reporting system and Sect. 3.5 the operational picture. Finally Sect. 3.6 describes how the individual parts are connected.

3.1 Main Objectives

Efficient information management is important in crisis situation and situation assessment includes numerous factors which will affect the final picture [4]. One of the most important challenges is how to collect relevant information and make sense of it in a timely manner so that response actions can be initiated in time. The key to making good decision is situation awareness which is achieved by analyzing available data collected from the field in combination with context and background data. Situation assessment includes assessing what the damage and needs are as well identifying potential cascading effects that needs to be taken into account. Improving the crisis response team ability to understand the situation, by providing efficient tools for structuring and analyzing the available information, can decrease the time taken from getting data to taking the necessary actions. To achieve this a system should support:

- Dynamic information gathering: Information that the personnel are asked to collect and details asked for in incident reports should be based on actual information needs active at the moment instead of relying on a fixed set of question. The information needs are based on the current situation type (e.g. geography, demographics, disaster, etc.) and other factors such as risk event (e.g. epidemics, starvation, injured people, etc.). In this way it is ensured that the questions asked to the personnel in the field is relevant to the current situation.
- Information need analysis: To support above point, the system should be able to assist the crisis management team in the task of identifying what information that needs to be collected.
- Automation and sense making: Algorithms and techniques for automatic deductions that reduce the time spent on structuring information and simple aggregation should be available which reduce the time to decision. To some extent, the system should also provide sense-making capabilities such as calculating risk probabilities.

3.2 Concept Overview

In order to meet the above described objectives, a concept with three main components is proposed:

(1) *Models* describing risk events: Models are used to assess the current likelihood of a specific risk event. The inputs to a model are information objects like flooding, power outage, crowds, etc. Each information object have attributes like coordinates, time, scale, etc. The models can then be used to automatically access information gaps, especially where the data flow is too large and too fast for a human operator to manage. See Sect. 3.3 for details.
(2) A *reporting system* used by personnel on the field in the form of a hand held device or similar. With the use of models these system can work on dynamic forms instead of static. Either the operator chooses the questions or the system adapts the questions depending on the situation. See Sect. 3.4 for details.
(3) A *situation awareness operational picture* (in a form of a GUI) that gives a filtered overview of the crisis area. See Sect. 3.5 for details.

The data collected from the fields via the reporting system (2) are feed into the operational picture (3). The personnel on the field are guided, in terms of what kind of data to collect, by the operators that has the overview of the situation (3) or by RFIs generated by the models (1). RFIs can both be manually or algorithmically managed. The interaction between the three main components are depicted in Fig. 1 and discussed in Sect. 3.6. A proof-of-concept implementation of this concept has been developed and described in Sect. 4.

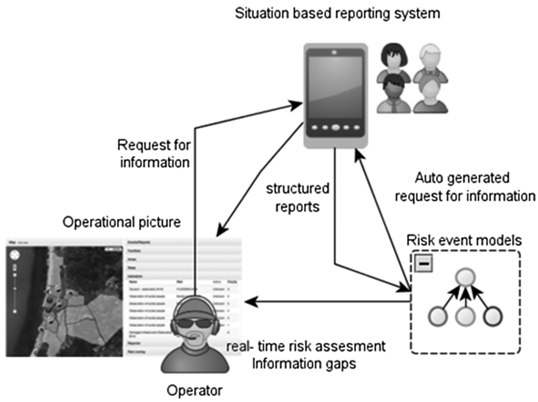

Fig. 1. Schematic overview of the information management system presented.

3.3 Risk Event Models and Information Gap Management

The concept described in this paper proposes models for aggregating, fusing and structuring information relating to a risk can be used to enhance the crisis management team ability to understand crisis situations. Moreover, the models can speed up the decision process. The top node of a model is the risk even itself (e.g. epidemic risk) and the branching nodes are indicators of the risk (e.g. sanitary problems). Each node represents events and indicators that contributes to the probability of the top node (e.g. Epidemic risk) to be true/happening (See Fig. 1). The model is created using a model development tool described in [5].

The idea is that relevant information (gathered on the field by the operators or sensors) are connected to, and can be access via, the leaves in the model which makes it easy to navigate through the information available. The models can also be used to manually, semi-automatically, or automatically calculate the probability of the risk based on the observed indicators. Besides providing structure to the information and giving estimate of the current risk, models can also be used for two additional reasons:

- For each observable node in the model an *information need* is associated. Therefore, the risk models can help the operator and the system to identify information gaps.
- To assess if the current assessment of a risk has too high level of uncertainty. For example, if weak indication is obtained from one source it can be necessary to confirm it.

After the identification of information gap the question is how to use the information acquisitions resources available to close these gaps. The information need can for example be filled by asking a questions to the personnel on the field that has access to the hand held device. This is where the RFI functionality can be used. The information needs are transformed into RFIs that can be distributed to the information acquisitions resources available. When collecting the RFIs one central aspect to take into consideration is the relevance of a certain question with the respect to the field personnel current situation (role, capabilities and task). Neglecting this aspect and broadcasting all questions to all personnel would overwhelm them with irrelevant and annoying questions. Therefore there is a need to carefully select the receivers to send the RFIs. There is a match between the question at hand and the personnel if either:

- The question is related to a location or objects that's close to the personnel on the field
- The question is related to any of the entities the personnel has previously answered
- There is a custom made rule/pattern that specifies that a certain question is relevant to specific situation

Depending on the resources available and their capabilities, situations where the crisis management team must prioritize which information gap to focus on can occur. This can be a non-trivial task in complex large scale crisis situation. Computer algorithms can be used to generate optimal resource allocation suggestion. The idea to calculate optimal resource allocations based on a models similar to the ones presented in this paper has explored in [6] in a military intelligence scenario, which is analogous to a crisis scenario in terms of constraints.

In the next section it is discussed how the RFIs are received and managed in the field by the reporting system.

3.4 Reporting System

The reporting system is designed to be run on a hand held device in the field. The idea is that a personnel in the crisis area can use it to create observation reports or to gather data explicitly requested by and then later upload/report in to the COP system (Sect. 3.5) located in a HQ. The reporting system user interface is dynamic in the sense that which input form fields that are displayed depends upon the RFIs that exists at the moment. The RFIs may be generated automatically based on an information gap (Sect. 3.3) or created manually. This follows the idea of generating a user interface based on information needs discussed in [7]. Each RFI has a priority that is used to determine displayed order and the user is to answer them in this order to ensure that the highest priorities are handled first. The priority can be set either manually or by an algorithm. A typical reporting workflow can look like this:

1. A field personnel creates a report by either receiving a RFI or selecting a form for the situation that the user want to report about.
2. The user answers questions related to the type situation that the user selected in step 1.
3. Optionally the user enters additional information if needed.
4. The user interface is updated (via the models) with questions that are related to the information provided based on the RFI currently active.
5. If the user has more information to report, steps 3 to 5 are repeated, otherwise the report is considered complete and the user submits it.
6. If the report matches an indicator in a risk model, the report will be connected to the indicator. The process of connecting reports to indicators can be manual, semi-automatic or automatic.

The heavy use of ontologies and semantic technologies is beneficial for making use of background data. If a user of the systems mentions a building that the system has some background data about, this data will be immediately associated to building mentioned and accessible in the app. The output (report) of the reporting system is represented as a set of RDF (Resource Description Framework) statements.

3.5 Operational Picture

The persons in charge of coordinating response actions have access to an interface where the location of each personnel on the field is visible. Other information can be displayed including objects like:

- Events/reports: Reports of event that has relevance to the situation assessment.
- Facilities: Hospitals, bridges, roads, etc. with information about their current status.
- Areas: Pre-defined areas the divided into administrative units or similar.
- Risks: An icon will represent if a risk occurs at the location. In the GUI information about the risk probability and impact can be found.
- Indicators: An icon will represent an observable factor at the location. In the GUI information about the indicators priority, status, location, etc. can be found.

3.6 Integration

The section describes how the risk event models, the reporting system and the operational picture benefits from each other and forms an integrated system for situation awareness in crisis situations.

The key technology used to implement the concept is ontologies. An *ontology*, in information science, defines a hierarchy of concepts within a domain using a shared vocabulary. Furthermore, it defines properties for each concept and the relationships between the concepts. An ontology can be used for several purposes in the context of the proposed concept: shared formal vocabulary, matching RFIs with the current reporting situation, enable automatic binding of incoming reports, and to speed up the input process by making suggestions based on the situation.

In essence, three categories of data are exchanged between the modules: RFIs, risk information and reports generated by the Reporting system. The reports created by the personnel on the field are fed into the operational picture as well as the risk models. Since the reports are represented as RDF statements which have a formal specification and precise meaning, it can be matched with the RFIs connected to the indicators in the risk models. Once the reported is connected to the model, a new risk index can be calculated. As soon as a risk index is updated, the operational picture is updated to reflect the changes. The risk event models feeds the operational picture with up-to-date estimates risk values. From this risk map overlays can be automatically drawn. This allows the operator to quickly get an aggregated view of the situation in contrast to only looking at individual observations.

A key feature of the proposed concept is the support for dynamic forms that take RFIs into account. RFIs can be manually created by the operator or as the result of an algorithm analyzing what the current information gaps are as based on the risk event models described in Sect. 3.3. The fact that ontologies are used to represent the RFIs and the fact that the reporting app use the same ontology (or mapping between) to represent the reporting situation makes it possible to apply standard graph matching techniques to find out if a RFI is relevant to an reporting situation. If the RFI is relevant to the situation, a new question will be added to the reporting GUI.

4 Implementation and Validation

The proposed concept has been implemented as a proof-of-concept prototype by integrating and extending research prototypes and open source software. The reporting module has been implemented as a native Android App. The support for risk event models has been implemented by extending the concept (Impactorium) described in [5] with new capabilities (see Fig. 1). The COP has been implemented as a web app using the Typesafe Play framework. Bootstrap and angular-js has been used to implement the COP GUI. The map service used is Google maps. The support for ontologies and semantic data has been implemented by supporting RDF and RDFS. SPARQL has been used to represent RFIs. The individual components have been integrated using RESTful webservices. All components are exchangeable and the system is not relying on a specific software.

The concept has yet to be validated in the field. The tool has however been demonstrated to crisis management personnel where mock-up scenarios (including a tsunami scenario in a Mediterranean country) were used to show the functionalities and the concept. Larger experiments will be performed in the near future. The idea to use models in the way that is described in this paper has not been validated in crisis management context. The method of using similar models in a military context has however proven to be useful [8].

5 Future Work and Conclusions

This proof-of-concept implementation uses SPARQL to represent RFI. At current date, these questions need to be formulated manually. Manual construction of these queries are only feasible if the user is very experienced with the SPARQL syntax and have basic understanding of how RDF work which is not reasonable to expect.

The concept presented is the product of fusion from many different research areas such as information fusion, information management, threat modeling and ontology based graphical user interfaces. The concept described in this paper has addressed generic challenges related to information management in a crisis situation with focus on reducing the time to decision by proposing an integrated solution for how information is gathered from the field and used for decision making purposes. The implemented concept use risk models, dynamic forms (for field personnel) and ontologies in order to understand a crisis situation faster.

The risk models are a preamble for the dynamic forms and information gap assessment. The ontologies gives structure to the information and can be used to describe information needs. Ontologies are also the core technique used to create dynamic context aware forms. The filtered COP map will further contribute to give a better overview of the situation as the components shown on the map is aggregation of information of the current situation via the risk models. The system can better support the crisis management team in doing correct decisions on actions to be taken and on which information need that is the most important. This is partly done by handling the information gaps problem and alerting when new crisis have, or might, arise. This combined allows for handling larger amounts of data at a higher rate than previous solutions.

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