INTEGRATING MESSAGE INFORMATION INTO DISASTER MANAGEMENT MAPS: TRANSFERABILITY OF A SYSTEM OF THE MILITARY DOMAIN

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ABSTRACT:

In disaster management it is of crucial importance to deal with numerous incoming messages and to visualise the geo-related information in a situation map appropriately. In this paper a solution of the military domain is analysed for its transferability to the civilian domain in order to automate this process. Tests were based on realistic messages generated in exercises of German disaster management organisations. The results demonstrate that despite domain-specific differences the basic data model of the military system as well as its approach for semantic augmentation provide a good basis for the requirements in disaster management. Extensions and further research will be necessary concerning the handling and visualisation of different types of uncertainty that regularly occur in disaster management messages, but are not yet covered by existing standards.

KURZFASSUNG:

Im Katastrophenmanagement ist es von entscheidender Bedeutung, zahlreiche eingehende Meldungen zu verarbeiten und die raumbezogenen Informationen in einer Lagekarte entsprechend darzustellen. Um diesen Vorgang zu automatisieren, wird in diesem Beitrag eine Lösung aus dem Bereich des Militärs bezüglich ihrer Übertragbarkeit auf zivile Anwendungen analysiert. Die Untersuchungen wurden anhand realistischer Meldungen aus Übungen von deutschen Katastrophenmanagement-Organisationen durchgeführt. Die Ergebnisse zeigen, dass - abgesehen von domänenspezifischen Unterschieden - sowohl das dem militärischen System zugrunde liegende Datenmodell als auch seine Vorgehensweise für die semantische Anreicherung eine gute Grundlage für die Anforderungen des Katastrophenmanagements bereitstellen. Erweiterungen und zusätzliche Forschungsarbeiten sind notwendig im Hinblick auf die Behandlung und Visualisierung unterschiedlicher Typen von Unsicherheit, die regelmäßig in Meldungen im Katastrophenmanagement vorhanden sind, aber noch nicht durch vorhandene Standards abgedeckt sind.

1. INTRODUCTION

During catastrophic events a disaster management centre receives hundreds of written messages with information concerning e.g. the situation at different crisis locations or movements and actions of relief units. A single person of the management staff is responsible for checking all the messages in order to decide which member of the staff receives which messages. This includes the selection of messages with information that should be integrated into a map of the situation. However, since this map is an essential basis for all decisions of the staff members, it needs to be as up-to-date as possible. Therefore, the aim of the presented work is to contribute to the reduction of time for sorting and displaying relevant information. The work of this project is especially focused on a suitable representation (model, visualisation) of uncertainty that is connected to the spatial information in the messages. Such types of uncertainty can be e.g. the uncertainty of the message content itself (unconfirmed information, inconsistencies between different messages), vague or ambiguous spatial information (“north of here”, “in front of the church”) or uncertainty concerning the actual observation time of the information and its current validity. For an efficient disaster management, such uncertainties should be considered in the decision process and therefore visualised in a map.

1.1 Related Work

For an automation of this sorting and displaying of messages, it is not only necessary to apply a system that is able to process natural language expressions. The system also needs to analyse the semantics of sentences, e.g. to dissolve references that are used in texts. There are quite a number of publications in different disciplines that are concerned with partial aspects of a transformation of spatial information from a textual to a graphical representation, e.g. concerning information extraction (Kaiser and Miksch, 2005), semantics of spatial terms (e.g. Tenenbrink, 2005; Tomai and Kavouras, 2005), spatial ontologies (Frank, 2003; Tomai and Kavouras, 2004) or the relationship between language and graphics from a cognitive viewpoint (Tversky and Lee, 1998). However, systems that actually interpret written spatial information and produce a graphical representation are rarely found in the literature. Some of the few examples are introduced by Egges et al. (2001) for the visualisation of car accidents and by Leidner et al. (2003) for the illustration of spatial references found in news reports.

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The system that is closest to the aims of this project is SOKRATES (Schade and Frey, 2004; Hecking, 2004).

1.2 The SOKRATES System and its Links to Disaster Management

Designed for the interpretation of military reports, SOKRATES consists of an information extraction part that automatically transforms the information of a message into a formal structure. This formal structure is very flexible and allows fields of object attributes to be empty if the information is not explicitly mentioned in the message. However, in order to represent the message content on a map, it is necessary to identify the corresponding symbol and its position in map coordinates. This requires a semantic analysis and post-processing by which missing information is calculated using an ontology with context and domain knowledge.

There are some striking similarities between the application of SOKRATES and this project. In both domains (military and disaster management) written messages are transferred to map entries. The forms that are used for the communication of reports are also very much alike: they consist of fixed entries (e.g. for addressees, addressers and time stamps) as well as a free-form text element where the actual message can be given in natural language (see Figure 1). Despite these similarities, there are also differences: examples are the different jargons and symbols, different tactical reasons why the map is used and a stricter regularisation in the military domain.

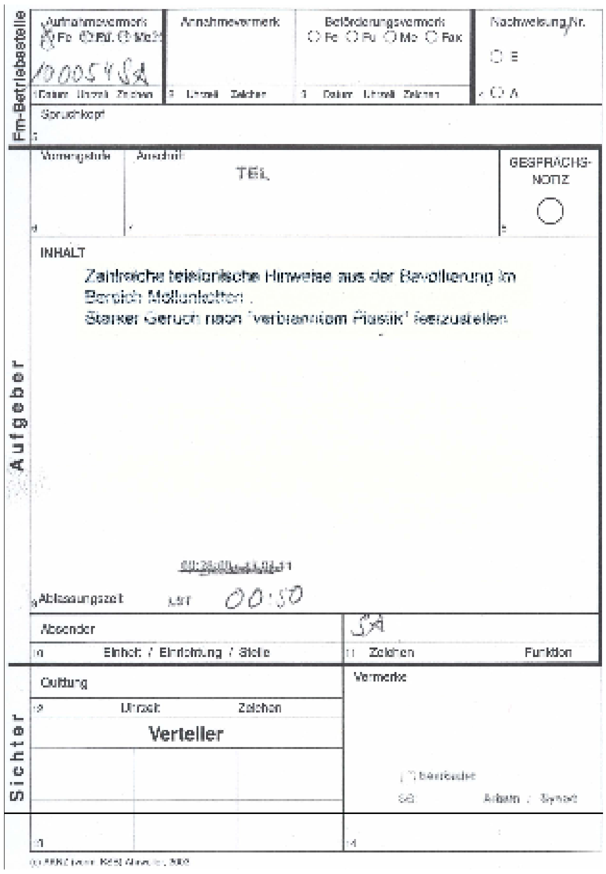


Figure 1. Example of a message generated during an AKNZ exercise (courtesy of Akademie für Krisen- management, Notfallvorsorge und Zivilschutz / Academy for Crisis Management, Precaution of Emergencies and Civil Defense, Ahrweiler, Germany). Translation of the message content: "Numerous hints by telephone from the inhabitants in the area of Möllenkotten. Strong smell of burned plastic perceived".

In the following, the results of an analysis are presented in which a transferability of the SOKRATES system to the disaster management domain is tested. The focus in the analysis is on the transferability of data models and visualisation models concerning spatial information as well as on the processing step of semantic augmentation in cases when missing or uncertain information needs to be calculated and suitably visualised on the map.

2. COMPARISON OF DATA MODELS

The ontology of SOKRATES is based on the C2 Information Exchange Data Model (C2IEDM, 2005), a military data model that supports the interoperability of command and control systems of the NATO partners. In the domain of disaster management there exist no real standards in Germany. The basis for an organised coordination in the case of an emergency are "Dienstvorschriften" (official instructions). However, they are only considered as recommendations and can be different in each federal state. Therefore, in order to evaluate the concepts used in SOKRATES concerning their applicability to the domain of disaster management, it was tested whether realistic messages generated in AKNZ exercises (cf. Figure 1) can be integrated into the existing ontology of SOKRATES.

Most of the information contained in the messages could be easily inserted into the ontology with only minor adoptions due to domain specific differences. Missing concepts were modelled according to existing international standards. Examples are messages concerning the lifecycle of resources (e.g. request, response, dispatch) addressed in OASIS-EDXL RM (2005).

Many concepts are already introduced in the C2IEDM but are not sufficiently elaborated for the current purpose because they are not the prime focus of the C2IEDM and SOKRATES. In order to capture the highly dynamic situations in disaster management, e.g. more details about the development of events are required. These include the possibly quickly changing status, geographical position and extension of affected areas in case of fires or toxic clouds.

Challenges for each ontology and logical programming language are the exclusive "OR" and negation in general due to the "closed world" assumption. Statements using these operators cannot be satisfactorily handled by the C2IEDM but regularly occur in disaster management messages, e.g. in a request for resources such as "either 2 wheel loaders or 3 excavators".

Uncertainty concerning e.g. the degree of trustworthiness of the data in a report or the reliability of the information source can be specified in the C2IEDM, although it is unclear if sender and receiver share the same definition of terms such as "fairly reliable" and "usually reliable".

Messages frequently contain other types of uncertainty that are more difficult to handle and not yet considered in the C2IEDM and SOKRATES. In the following list some examples for these types are presented and in section 3 suggestions for their visualization are discussed:

- *Time*: The duration of events or actions can often only be roughly estimated. A statement such as "probably lasting into the next day" can be approximated by a temporal relation with open-ended intervals ("event A starts before event B ends", here: next day starts before the current action ends). However, this relationship does not cover the implicit assumption about the remaining time of the total duration of B, which is actually dependent on the time interval from now on to the start of A:
  If an action B already requires hours before the new day starts then the probability is rather high that is lasts also several hours into the new day. In the case of the aforementioned message the time of transmission was 11:20 pm; thus with only 40 remaining minutes of the current day it is more likely that action B will last less than an hour into the new day.
  However, such implicatures that are associated with the text by human beings when reading a message, need to be more thoroughly investigated and made explicit before they can be integrated into a data model.
- *Spatial information*: The exact location and boundaries of an object are often not available (difficult to measure, constantly changing as in the case of fires or gaseous substances with only selective measurements and observations as indicators of the general development). For spatial information, again, context is essential. Examples are different definitions of the area of a street section: in car navigation the lanes are the important parts whereas the complete environment including adjacent buildings need to be considered in case of a flood or toxic cloud.
- *Numbers*: The numbers of injured or dead people can be vague or unknown. Both fuzzy numbers ("approximately 30") and quantifiers as "some" or "numerous" result in intervals of possible values. Again, a suitable definition relies on tests with human subjects in order to identify the interval boundaries depending e.g. on the context or the cultural, educational, etc. background of the reporting person. In the German disaster management the concept "MANV" = "Massenanfall von Verletzten" is used, which describes an event where many injured and possibly dead people are expected. For the purpose of standardisation a few German federal states also introduced a classification of MANV in four levels that define an approximate size of the event. However, they are not officially used in all federal states of Germany yet.
- *Potential danger*: Some messages also include warnings that objects might be in danger in the near future. Such alerts have to be taken seriously into account for further action planning. Therefore, an appropriate model for such situations needs to be integrated in the disaster management ontology.

3. COMPARISON OF VISUALISATION MODELS

The basis for the comparison are the NATO military map marking symbols of the "Land Component Handbook (APP-6A Map Symbology)" and the tactical symbols of the "Dienstvorschrift 100 (DV 100 (SH))" of the German federal state of Schleswig-Holstein. Both standards serve as a reference to generate situation maps in the domain of disaster management: While the APP-6A (2001) is applied for the military, the DV 100 (SH) (2003) is applied for civilian fire brigades.

The "Land Component Handbook" is divided into five sections representing size and type indicators on icons (number: 16), units and functions icons (115), equipment and weapons icons (97), icons for operations other than war (35), and graphic control measures (158). The "Dienstvorschrift" provides 47 tactical symbols, which are divided into the classes basic symbols (11), denomination of tasks (8), indication of size (5), additional symbols (20) and other symbols (3).

Based on written messages generated during an AKNZ exercise (cf. Figure 1) the two standards APP-6A and DV 100 (SH) are analysed with respect to their suitability for representing visually uncertainty that is connected to the information content of the messages. Before the results are presented an overview of the exercise's simulated disaster situations and of the identified uncertainties in the corresponding messages is given:

For the following catastrophic events messages were written and delivered to the disaster management centre:

- Derailment of a suburban train and subsequent crashing of cars into a building causing fire
- Damage to persons and impassable roads due to windthrow
- Fire in a waste separation plant
- Fire nearby a chemical plant

In the corresponding messages (here: 27) to these catastrophic events several pieces of uncertain information could be identified:

- With regard to uncertainty of the message content itself phrases like "MANV" [which level? cf. section 2], "Probably 10 injured persons" and "Several persons from Buettenberg complain about shortness of breath and burning eyes respectively" were reported.
- With regard to vagueness or ambiguity of the spatial information connected to the messages phrases like "Site of damage [location!]: whirlwind [event!]", "Fire close to KWS Company is spreading increasingly [direction?]. More buildings are seriously threatened [which ones?]" and "Pollutants [which ones?] are leaking in great quantities [where?]. Relief units complain about shortness of breath, even beyond the barrier [where exactly?]" were reported.

Whereas the DV 100 (SH) - as a recommendation for civilian fire brigades in disaster management on federal state level - doesn't incorporate tactical symbols of military dangers, the APP-6A provides icons which are also relevant in civilian disaster management, i.e. icons for "fire" and "radioactive area" as well as "biologically / chemically contaminated area". Thus, "fire" is the only one of the simulated catastrophic events which can be represented in disaster management maps based on the standards of both APP-6A and DV 100 (SH).

With focus on the graphical representation of the uncertainties mentioned before, the only phrase which can be suitably realised with tactical icons of either of the two visualisation models is “probably 10 injured persons” (see Table 1). The other phrases with uncertain information can’t be taken into consideration by the available standards. However, there are certain possibilities to account for uncertainties: In the APP-6A standard icons for combat units as well as icons for equipment and weapons are marked yellow if their attitude or affiliation is “unknown”, whereas the icons for friendly, neutral and hostile combat units / equipment and weapons are marked blue, green and red, respectively. Furthermore, dashed lines are used for areas and boundaries in case of “Friendly Planned / On Order” and “Enemy Suspected / Anticipated”. Axis of advance and direction of attack are also characterised with dashed lines when the following uncertainties are existent: “enemy anticipated”, “anticipated enemy ground” and “friendly aviation planned or on order”.

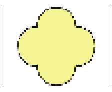
	Map symbology	
Types of uncertainty	APP-6A	DV 100 (SH)
uncertainty of the message content itself	 “unknown land unit”	 “probably 10 injured persons”
vague/ambiguou s spatial information	 “enemy suspected / anticipated”	–
uncertainty concerning time of an information and its current validity	–	 “acute danger: chlorine”

Table 1. Tactical symbols of APP-6A and DV 100 (SH) representing uncertain information for communication of disaster information (when is acute?)

As in the visualisation standards presented above the graphical representation of uncertainty information is possible only in a limited way, in the following symbols and cartographic methods from other works are presented: For example within the framework of an experiment on the effects of situational uncertainty on decision-making St. John et al. (2000) depict levels of uncertainty with graphical symbols (Fig. 2, top). Kim and Kesavadas (2004) demonstrate the use of blurred icons for uncertainty visualisation. The icons were generated with Gaussian blurring to simulate uncertain casualties. The one at the centre is for 100% certain casualty and the rest are blurred depending on the radial distance from the centre (bottom, left). MacEachren et al. (2005) in a way combine the two former examples in their point symbol sets: They depict uncertainty with variation in saturation, crispness of symbol edge and transparency of an additional symbol (bottom, right).

When dealing with disaster management and the visual representation of information uncertainty, one of the most fundamental research questions still is whether incorporating uncertainty information acts to clarify the map (Edwards and Nelson, 2001) or clutter the map (McGranaghan, 1993). This could be answered if there were more user tests concerning the readability of situation maps displaying uncertainty (Harrower, 2003). However, Keuper (2004) contributes to closing this research gap by evaluating how data users interpret uncertainty in spatial data products, and how the incorporation of uncertainty information influences decision-making. The same applies to the review paper of MacEachren et al. (2005), who take up these current research questions and research needs. They conclude with the identification of seven key research challenges in visualising information uncertainty, particularly as it applies to decision-making and analysis.

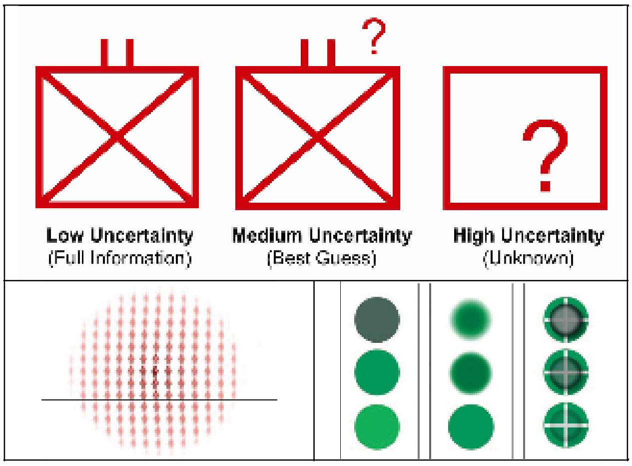


Figure 2. Selected symbols and cartographic methods for visualising levels of uncertainty: Tactical icons (top; St. John et al., 2000), blurred icons (bottom, left; Kim and Kesavadas, 2004) and point symbol sets (bottom, right; MacEachren et al., 2005)

4. SEMANTIC AUGMENTATION

In order to visualise the information content of messages, more than a suitable calculus and symbols for representing uncertain information need to be available. The messages themselves often include spatial references where general, application-dependent or context knowledge of previous messages (e.g. position of the sender) has to be considered in order to identify the coordinates for the placement of the symbols in the map. A disaster management system needs to be based on a GIS that includes geo-information of cities with e.g. streets and house numbers as well as locations of schools, hospitals or other important facilities. In particular, street crossings or street sections can be computed using the GIS functionality.

However, complex calculations are often necessary to achieve suitable map coordinates for spatial references such as “in front of object X” or “south of city Y”. One of the aspects that needs to be considered when dealing with spatial references (such as the deictic adverbials and prepositions “behind” or “in front of”) is to identify the reference frame, the relatum (Levelt, 1989). In the example “in front of object X”, the question has to be answered if the concerned object has a clear front side. If a front side of X is specified in the database, then it is assumed in SOKRATES that this is the referred “front” of X. Otherwise the assumed “front” is the part of object X that is closest to the reporting person or organisation. SOKRATES already incorporated a number of this useful heuristic rules in order to disambiguate linguistic references (Schade and Frey, 2004).

However, only a small amount of context is considered in these rules, yet it can have a great influence on the correctness of the chosen interpretation. Depending on the context, the message "south of city Y" might imply that the associated area reaches only as far as city Y2, the next city south of city Y, otherwise the sender of the message would have mentioned "south of Y2". This point of view is currently realised in SOKRATES but can be incorrect depending on the context: the message might include a much larger area, even beyond Y2, where it is only definite that the affected area starts south of Y. Limiting the displayed area on the map from Y to Y2 might be too restrictive and may lead to misconceptions and, hence, wrong decisions of the staff members at the disaster management centre.

Another example of the importance of context becomes apparent by the message "relief units complain about shortness of breath, also beyond the barrier". This text implies for a human interpreter that an invisible cloud of toxic particles that causes the breathing problems is already beyond the expected borderline. Thus, the message does not only include information about the health of the relief units but should also trigger the extension of the cloud area in the situation map and a suggestion to enlarge the blocked area. However, such an inferred conclusion requires more complex ontological knowledge processing and a large database of general knowledge e.g. about the reasons for shortness of breath in the current situation.

The C2IEDM already includes a concept "context" where contents of different reports can be combined and evaluated especially for planning purposes, proofing that the NATO standard does already offer some basic concepts for modelling this important aspect of disaster management messages.

5. CONCLUSION AND OUTLOOK

The demands of disaster management scenarios, e.g. the detailed registration of the dynamic situation, are not (yet) covered completely by the standards of the military domain. One of the major limitations is that the latter do not include a data model respectively symbolism for most types of uncertain information. Despite its indisputable usefulness, so far context knowledge is only marginally considered in the prototype of SOKRATES. However, the heuristic rules of SOKRATES for the semantic augmentation are very often applicable for messages of the disaster management as well. Additionally the ontology of SOKRATES was flexible enough to integrate most of the message content with only minor adaptations. As a consequence, the SOKRATES system provides a good basis for disaster management applications, but needs to be adjusted and further extended to the requirements of the disaster management domain. This extension will be guided by further tests with realistic scenarios and by existing international standards such as CAP developed by OASIS (OASIS-CAP, 2005).

One of the testbeds for the extended and adopted system is the integration of its information extraction and semantic augmentation components in the software system Disaster Management Tool (DMT). The DMT (Markus et al., 2005) is one result of the multidisciplinary Collaborative Research Center 461: "Strong Earthquakes: a Challenge for Geosciences and Civil Engineering" and is designed for disaster mitigation, preparedness, disaster response and recovery. As part of the DMT the Management Information System (MIS) conducts the aggregation, selection and distribution of information relevant to specific actors of disaster response. If possible this information is visualised in a GIS for a quick overview of the current situation. A component based on SOKRATES as part of the MIS is expected to improve the disaster management in two fields. First, the automatic analysis of reports offers the possibility to check if all necessary information is provided, to extract orders and send them directly to the corresponding units and to keep the map of the current situation as up-to-date as possible. The second one is to improve the usability - especially for inexperienced users. Through queries written in natural language the user shall be empowered to communicate with the MIS in order to easily extract the desired information.

Further developments and applications of SOKRATES can be realised in close cooperation with the Research Training Group (RTG) "Natural Disasters" at the Universität Karlsruhe (TH). Using state-of-the-art mathematical techniques and considering the entire chain of effects of natural disasters the RTG's current projects focus on precaution and management of natural disasters and thus provide several suitable testbeds. One of them, for example, is an ongoing project which is to develop an early-warning system with improvements in disaster management and risk communication (cf. Kaempf et al., accepted): First of all, relevant information for a flood early-warning-system is identified on the local and regional scale. In a next step this information will be provided online in order to inform the population about the status quo and to mobilise them in sufficient time if necessary. In this context the integration of an extended and adopted SOKRATES system could serve as a valuable decision support for risk communication and disaster management - not only in case of a flood but also in case of other natural and man-made hazards as well.

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