IMPROVING EMERGENCY MANAGEMENT BY FORMAL DYNAMIC PROCESS-MODELLING

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ABSTRACT: In the past years, as natural disasters are increasing all over the world efforts in disaster prevention measures and disaster and emergency management systems (DEMS) are expanded in research and practice. In Germany especially the emergency management in case of flood or high water situations plays an important role because of serious flood incidents in 1997 and 2002.

Advanced emergency management systems provide a bundled, structured information access for emergency management actors using databases, GIS and internet technology. Nevertheless, the activities, tasks and also decision processes which occur in the emergency management situation are mainly neglected or less supported by these emergency management systems. In this paper, a process-oriented approach to emergency management using ICT is presented. A meta model for the process modelling of emergency management activities is presented and an existing formal process model which allows dynamic changes of pre-modelled processes is explained. A simplified scenario in the context of operational flood management finally points out the applicability of this approach.

KEYWORDS: dynamic process-modelling, emergency management, emergency management system.

1 INTRODUCTION

Nowadays, emergency management plays an important role because of the increasing number of natural disasters all over the world. Furthermore, serious terrorist attacks happened in recent years which also implicated stronger needs for flexible and reliable emergency management systems. Concerning natural disasters, Germany has to cope mainly with severe floods and high water situations. Therefore, research in the field of natural disaster prevention and management focuses on preventive and operational flood and high water protection. As a result of serious flood incidents over the past years, the German republic has tightened the regulations in the emergency management area. The public authorities on the community level have to prepare detailed emergency plans, including various disaster scenarios. These plans exist mainly as paper copies and include various information types, e.g. contact dictionaries, responsibilities, material locations, reporting channels, measures descriptions and maps. As in case of a disaster incident, many different actors and institutions have to work together, and as the appropriate countermeasures have to be undertaken in the fitting place with the effective equipment in short time, the existing emergency management plans in form of paper copies are insufficient on the operating level. For this reason, integrated flood information and alert systems are being developed and are already in use in some parts of Germany. These – generally web-based – information portals bundle functionalities like high water forecasts, alerting, geographical information, information about available equipment and resources, and contact information. As a result, the emergency managers and action forces have quick access to necessary information about the current disaster situation. Nevertheless, these emergency information systems generally do not support emergency management activities in form of formal process descriptions. This means that some activities and workflows which have to be undertaken in case of a disaster incident could be formally modelled prior to the incident. Hence, emergency managers and forces would be guided by the emergency management system. It is the nature of emergency scenarios that many unforeseen circumstances arise so, the above prepared processes – encoded in the emergency management system – have to be changeable. Every management participant, using the system's processes in case of an emergency, should have the possibility to change them to his needs and to the situation's conditions. This paper focuses on the aspect of improving emergency management by the use of formal process models. Dynamic process modelling as a method to change process instances during runtime of the emergency management systems will be introduced.

After analysing emergency management plans and related regulations, requirements of process modelling of activities for natural disaster incidents are derived. Then, process modelling of emergency management activities on the basis of a meta model is introduced. Subsequently, formal models for dynamic process modelling are analysed with regard to their applicability. A simplified scenario is used

to illustrate the dynamic process-oriented approach. Finally, related works are mentioned and a conclusion is given. In future works, the presented approach will be implemented in form of a prototypical system and will be evaluated in the context of a disaster control scenario.

2 EMERGENCY PLANS AND RELATED REGULATIONS IN GERMANY

Concerning disaster management in Germany, the local public authorities are mainly responsible for disaster control planning. They have to create emergency plans by law. These plans consist of alert plans and of operational plans for different possible disaster types. Especially the emergency plans for flood incidents are drawn up in great detail and are extensive because of the past experiences with high water disasters.

These flood emergency plans [e.g. Einsatzplan Stadt Hennef 2003] generally contain the following points in greater detail:

- Contact information of all relevant authorities, relief organisations and forces
- Organisational chart
- Members of the disaster control staff
- Material and equipment information
- Communication channels
- Operational plans (water level, activity, required resources, party in charge)
- Maps (endangered areas, evacuation, water levels etc.)
- Especially endangered objects
- Information sheet samples for the population

Furthermore, a nation wide regulation [FwDv 100 1999] exists, which defines the organisational structure and the command and control processes for the forces and the activities in disaster management in detail. This regulation includes i.e.

- Organisational chart of the incident command unit
- Assignment of tasks of incident command unit members
- Structure of operational units (number of persons, skills etc.)
- Structure of an order/instruction (order scheme)

In order to improve disaster control management in terms of respond time, quality and effectiveness, ICT is used in research and in practice to structure information of document-based disaster control plans. Disaster management information from the participants (public authorities, fire departments, relief organisations, hospitals) are stored in databases and web-based access to this information in form of tables, maps and lists is offered. However it is not taken into account that disaster emergency plans and related regulations and documents also include information about the processes which have to be undertaken in disaster scenarios. Operational plans especially, but also communication channels and command and control regulations, describe chains of activities triggered by certain events (e.g. water level). In addition to an ICT-supported information supply, the processes of operational disaster management have to be modelled and graphically presented, so that the disaster control actors may be guided by a process-driven emergency management system. In the following section, modelling of emergency management activities is being focused on. Requirements for this process modelling procedure are established.

3 REQUIREMENTS FOR PROCESS MODELLING OF EMERGENCY MANAGEMENT ACTIVITIES

In order to better support users of operational emergency management systems, processes, too, should be explicitly integrated into the system. These processes are based on formal process models and describe the relevant activities and counter measures depending on the respective case of emergency. In this context, a process is defined as a temporarily and factually logical sequence of activities, which are necessary for a specific task's completion [Becker and Kahn 2005]. Process modelling for operational emergency management activities has to meet the following requirements:

- simple, easy understandable process model
- comfortable, intuitive visualisation of processes
- possibility to dynamically change predefined processes
- tracking of started processes
- storage of finished processes including dynamic changes

As emergency management systems are used in exceptional situations and not under day-to-day working conditions, the emergency management participants are not well experienced with the usage. Although regular training sessions may increase the experience, the models which are used to describe the emergency processes should have a simple, easy to understand representation. This means that a formal process model with only few model elements may be more suitable for the conditions as long as the common patterns (sequence, parallel split, synchronisation etc.) are supported [WfMC 1999]. Furthermore, an intuitive visualisation of the on going processes to the user is crucial for an application in the field of emergency management. The actor should always be able to get an up-to-date picture of the current and planned activities and events, which are represented by the modelled processes. He should be able to easily follow the sequence of planned emergency actions. But as only a part of the emergency management activities can be planned in advance and as changes occur frequently, the user should have the possibility to change modelled processes during runtime.

Enabling the user to change pre-modelled processes during runtime allows the emergency manager's expert knowledge to be entered into the system. Otherwise, the user might try to bypass the system as to not follow steps he wouldn't consider appropriate for the current emergency situation. The suggested dynamic changes of processes during runtime in this context are defined as changes which occur regularly. This implies a better support of the change management (user interface, versioning etc.).

One of the main goals of emergency management systems is to deliver an up-to-date description of the emergency situation and the status of the various undertaken actions. This is the reason for presenting the status of commenced

emergency processes to the user. Such tracking of started processes should also be integrated into the graphical representation of the emergency management processes. Finally, the processes actually carried out in case of emergency – including the changes made by the users during runtime – should be stored in the system after termination of the emergency management. The stored processes could serve as logs for the completed emergency case and may also be integrated into the emergency management system as best practice examples for future cases.

Following the requirements explained above for process modelling of emergency management activities, the next two sections introduce the approach and existing formal process models which both shall lead to a process-driven emergency management system.

4 PROCESS MODELLING OF EMERGENCY MANAGEMENT ACTIVITIES

Real processes in disaster and emergency management are of various types. Some of them can be derived from documents described in section 1 or consist of lessons learned. Others are in mind of the experts, leading the emergency and disaster management. In order to realise a process-driven emergency management system, the various processes have to be structured or/and classified somehow. Furthermore, as mentioned in the previous section, it has to be possible, to change started processes in case of an unforeseen change in conditions or in case experienced emergency managers like to add extra alternatives.

On the level of emergency management activities, every process is derived from the meta model depicted in Figure 1.

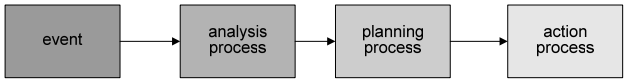

Figure 1. Meta model: emergency management activity.

This meta model generally describes the meta processes of an emergency management activity in a process-driven emergency management system. The event is the initial starting process. In the context of operational flood management, this could be a certain water level at a stage measurement station, but also a message from action forces about an incident. During the analysis process, the incident's conditions are analysed. Location, dimension, and type of incident are examples for analysis criteria. In the planning process, possible actions are planned based on the results of the analysis process. The planning includes, e.g. checking the availability of skilled forces and suited material and equipment for possible actions. Thereupon, the action process is started. In this process, the real emergency management activity – like evacuation of people, dike reinforcement etc. – takes place.

It is important to mention that not every meta process of this model must be used for the modelling of a certain process. For instance, if it is clearly specified in advance which action has to be undertaken in case of a certain measurable event, the analysis process is obsolete. This is often the case for actions which can be prearranged and which are dependant on the rise of a river's water level as long as the level do not pass a certain limit. For some process types, even the planning process itself is skipped. One example would be the action of a specified reporting channel if a certain event occurs.

In order to specify and structure the various activities in emergency management towards a process-oriented approach, a further refinement of process types is necessary. Concerning the planning process of the meta model, one can distinguish between planning of resources (forces, equipment and material) and planning of "routes" in emergency cases (evacuation routes, public transportation routes etc.). Furthermore, all processes of the meta model can be automated – e.g. automatic trigger from a gauge measurement station with a GSM-connection – or manually controlled. Further analysis of the emergency management processes will result in a more refined process type structure.

The following section addresses formal process models which support dynamic changes of processes, which is crucial to emergency management processes.

5 FORMAL PROCESS MODELS FOR DYNAMIC CHANGES IN EMERGENCY MANAGEMENT PROCESSES

Referring to the requirements described in section 2, the formal process model which can be used to model emergency management processes should firstly be understandable for practitioners and secondly should permit changes to pre-modelled processes during the execution phase of these processes. The process-driven emergency management system should, for example, enable the user to insert new activities in the pre-modelled process. Nowadays, many different formal process models (workflow models respectively) exist. But only few of these process models support changes of the process instances during runtime [Adams et. al 2006]. Mainly, these are the so called *worklets* [Adams et. al 2006] which are implemented for the workflow environment YAWL [van der Aalst 2003] and the formal workflow model with change operations $ADEPT_{flex}$ [Reichert and Dadam 1998]. In the first case, the dynamic change of process instances is realised by worklets. These are complete process pieces which can be created and stored in a repertoire during execution time of the process instance (see Figure 2).

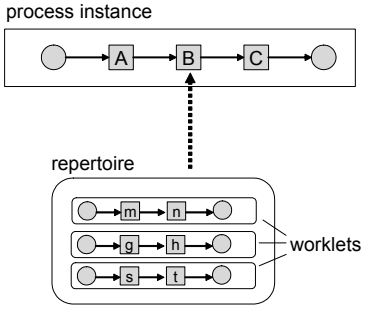

Figure 2. Worklet example (simplified).

The worklets serve as detailed sub processes for an activity of the process instance. The choice of the worklet out of the repertoire during execution of the activity is made by user-definable rules. This approach, which always demands a pre-modelled, more abstract activity on the process instance level, is not considered to be flexible enough for emergency management processes. Additionally, the rule implementation has to be handled by the user.

The ADEPT model is a graph-based approach using formal syntax and semantics. In contrast to other more complex formal process models, ADEPT allows a fast analysis and verification of the formal process structure which is important for process changes during runtime. Furthermore, its intuitive and structured representation also enables non-computer experts to change the processes [Reichert and Dadam 1998]. This is especially important for process-driven emergency management systems as mentioned in section 2. The ADEPT base model provides task sequences, conditional and parallel branching (AND-split, OR-split, AND-join, OR-join), and loop backs (see Figure 3).

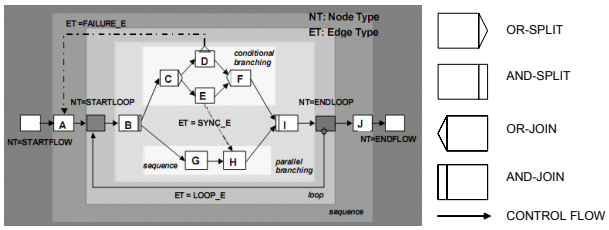

Figure 3. ADEPT base model [Dadam et al. 2000].

They are organised as symmetrical blocks which can be nested but do not overlap. $ADEPT_{flex}$ provides delete- and insert-functionalities for activities of process instances. Thus, dynamic changes in emergency management processes can be realised. A detailed description of the various dynamic features of $ADEPT_{flex}$ is given in [Reichert and Dadam 1998]. In the future, this formal flexible process model, allowing dynamic changes, will be tested for use in a process-driven emergency management system.

In the next section, a simplified scenario of emergency management processes will be presented to illustrate the approach and models described above.

6 SCENARIO

After the introduction of the meta model for emergency management activities and a short description of the formal process model ADEPT, a simplified scenario in the context of operational flood management is explained. For the process examples, the graphical representation of the ADEPT model is used.

It is assumed that during a flood incident of a river, passing through a city, a flood embankment was overwhelmed and that the disaster control forces have established a wall of sandbags to prevent the water from flooding a city district. Then, the radio operator on site sends a message to the disaster control centre, that the sand bag wall is washed out. The operator of the process-driven emergency management system triggers the event "sandbag wall washed out". As a result, the analysis process, depicted in Figure 4, is started. As countermeasures, the system suggests to install water pumps, requiring emergency power generators to be deployed.

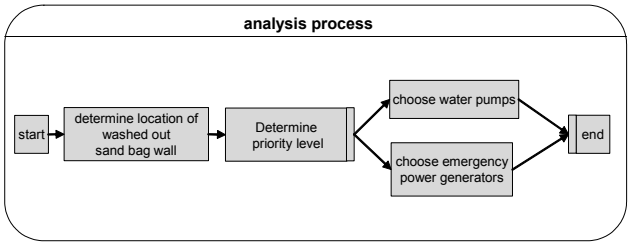

Figure 4. Example of analysis process.

In the planning process (see Figure 5) "installation of power generators" it is taken into account that a supply of diesel fuel is necessary to run the generators.

Thus, locating diesel fuel tanks and finding traffic routes to possible generator positions are included in the planning process. It may be the case that various paths of travel are impassable. The location of the generators is changed until a feasible traffic route is detected (see loop in Figure 5).

Finally, the action process is started (see Figure 6). That means that instructions are given to the responsible forces to deliver the generator units whose location and place of installation were determined in the planning process. Diesel fuel is also delivered. The units' movement may be tracked by the system, so that the activities' current state in the action process is permanently visible to the emergency manager.

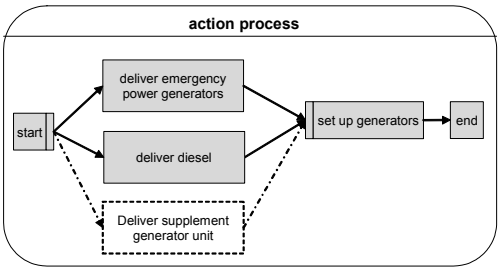

Figure 6. Example of action process.

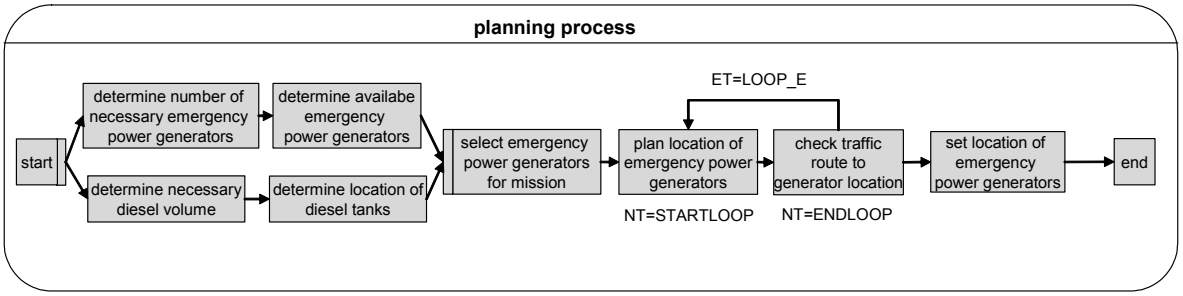

Figure 5. Example of planning process.

As is the case in this scenario, the responsible emergency manager notices that the last routine maintenance check for the power generators in question has been too long ago. Hence, he decides to deliver an extra generator unit. Therefore he adds the activity "deliver supplement generator unit" to the action process (dotted elements in Figure 6). This user initiated operation represents a dynamic change of the pre-modelled process.

Following this section, related research projects in the field of flood and disaster management systems are mentioned.

7 RELATED WORKS

In the sector of operational flood management, there are many national and international projects. In this context, mainly the Flood Information and Warning System FLIWAS has to be mentioned. This system was firstly developed within the scope of the project [NOAH 2007] but was later also integrated into the subject-related research projects [VIKING 2007] and [HIS 2007]. FLIWAS is an extensive web application for the operational flood management which includes inter alia modules for resource management, evacuation, measurement and monitoring, and emergency plans. The approach also offers basic workflow features for the emergency plans, but these features do not focus on workflow changes during runtime, nor do they offer sophisticated graphical representations of the workflows and their status (started, at work, finished). In the research project [OK–GIS 2007] (Open disaster management with free GIS), a prototypical disaster management system is developed with open source software. One part of the project – which focuses on the management of spatial data – is to develop reusable web-based GI services as platform independent components which can be linked together using an orchestration engine [Weiser et al. 2006]. In contrast to the approach presented in this paper, services (evacuation calculation etc.) and non human-centric processes are assembled to model disaster control measures. Furthermore, the EU-project [OASIS 2007] (Open Advanced System for dISaster and emergency management) is in a broader sense related to the work presented in this paper. It focuses on the definition of a generic crisis management system to support the response and rescue operations in case of large scale disasters. In contrast to all research works mentioned so far, the approach presented in this paper focuses on the processes occurring in emergency management. On the basis of formal process models, the emergency management will be supported by pre-modelled emergency processes which are dynamically changeable during the emergency incident.

8 CONCLUSION

In this paper, dynamic process modelling of emergency management activities in the context of emergency management systems is introduced. Starting with an analysis of emergency management plans and related regulations, requirements for a process-driven emergency management system are drawn up. On this basis, a meta model for the process modelling of emergency management activities is formulated and an existing graph-based formal process model is explained. It allows for dynamic changes to processes during runtime which is considered crucial to emergency management. Combining the meta model of emergency management activities and the formal process model, a simplified scenario in the field of operational flood management shows the applicability of the introduced approach. Further research will focus on the refinement of the meta model for emergency management activities, on the analysis of expert system aspects and on the linkage of emergency management processes to GIS-objects. Furthermore, a prototypical system will be developed in order to evaluate the presented approach in a disaster control scenario.

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