IMPROVING RESOURCE MANAGEMENT IN FLOOD RESPONSE WITH PROCESS MODELS AND WEB GIS

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Abstract

Introduction

In many regions in Europe one of the major natural disasters are floods which may cause high damage of property (e.g., Elbe flood 2002: 11 billion Euros in Germany) and may also threaten human lives. Despite the development of advanced flood protection measures, a hundred percent protection against floods is never possible. Therefore flood response management has a significant importance. Response operations like dike defence or evacuation have to be carried out by various organizations which have to work together under extreme conditions. The management of resources (e.g. vehicles, materials and equipment) is a crucial part in flood response and it is also a challenging task. Firstly, resource request procedures are rarely clear; secondly, an up-to-date overview of available resources belonging to different organizations is often missing; and thirdly, resource management support does not sufficiently include relevant situational information (e.g. resource locations, flooded streets).

Theory and method

In this paper, a new approach for an IT-supported process-based resource management is presented. It combines process modelling of resource management procedures with GIS techniques to support retrieval and allocation of resources taking into account their availability, their distances to the flood defence locations, predicted inundated areas and resultant potentially flooded streets.

Results

As result, a software prototype has been developed which provides a web client interface for

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disaster managers. The resource request and allocation procedures are modelled as processes. The process management system guides the disaster managers in their tasks and situational information is provided through a webGIS client interface. This combined approach helps to improve the challenging resource management in flood response. An IT-supported resource management process is described for a dike defence scenario at the Rhine River in the state of Hesse in Germany to clarify the approach and to show its potential for practice.

Introduction

Germany, as a country with 85 rivers longer than 100 kilometres and a high population density is heavily exposed to the risk of extreme flood events, as the huge floods of the Elbe in 2002 and of the Oder in 1997 have shown. Although great efforts in reducing the risk of floods have been undertaken, a hundred percent protection is never possible. Therefore, flood response management is of capital importance. Flood response management is characterised by a complex environment. Various organisations and public authorities have to carry out response operations together under exceptional, time-critical conditions. Dike defences and evacuations, as the major operations in flood response, involve different organisations which provide personnel and resources as vehicles, materials and equipment. One challenge of flood response is the management of these resources (Auf der Heide, 1989). After-crisis reports of the Elbe flood in 2002 have revealed certain deficiencies concerning the management of resources (Kirchbach, 2002). It was mentioned that, inter alia, information about resource location and availability was insufficient and that resource request and allocation procedures where unclear. These conditions lead to non-transparent resource allocation and cause difficulties in the target-oriented application of available resources so that response operations are delayed or may even fail.

One goal of the research project "Process-based cooperative emergency management for water infrastructures" – funded by the German Research Foundation (DFG) - is to face these problems with use of IT-methods in order to improve future resource management in flood response with focus on the districts level. Therefore, a combined method using process models and GIS technologies is developed. Other recent research projects in emergency management (Peinel et al, 2007) or flood response (de Gooijer et al, 2007) also propagate process-oriented IT-support which indicates the potential of this method.

In the next section important aspects of resource management in flood response in Germany are described. Then the overall approach of a process-based emergency management for flood response is shortly introduced. After that follows a section which focuses on a combined method using process models and GIS technologies to better support resource management in flood response. This method is demonstrated with an application scenario: resource ordering and allocation for a dike defence operation at the Hessian part of the Rhine. The paper concludes with summary and discussion.

Resource management in flood response in Germany

In Germany, flood response management is the duty of the districts and the cities. They have to set up flood response plans by law. In the case of severe floods they have to install an emergency operations centre (EOC) which coordinates the response operations in the district or city area. The municipalities in the district may install one or more incident command centres on site depending on the flood conditions. The coordination and allocation of resources are managed on the district level. Inter-district resource requests are handled on the regional level by a crisis unit which is also established. Besides public authorities including fire departments, also non-public relief organizations as the Red Cross provide resources for flood response. The German Federal Armed Forces and the German Federal Agency for Technical Relief (THW) take an exceptional position in flood response. They are both under the control of the German Government, but they can support the flood response with mainly self-organizing units by requests of administrative assistance.

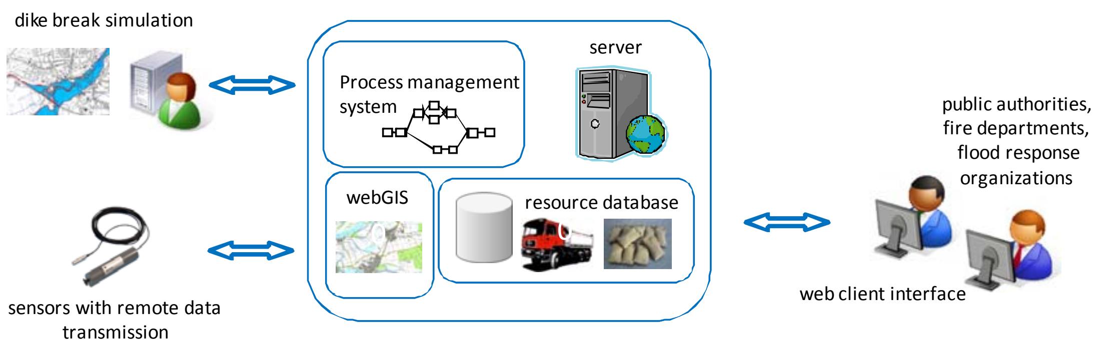
As the emergency operation centres of districts and cities are in general most closely located to the operation areas, the major part of resource management is taken over by their control staff. The efficiency of resource management of the EOCs is highly dependent on the amount and quality of provided resource information and on situational information such as information about predicted inundated areas and potentially flooded streets. Resource information includes descriptions about vehicles, materials, equipment and also about their quantities, storage locations, availability and contact information. Parts of this information are listed in the flood response plans of respective districts and cities. There are also first attempts of certain federal states to provide some of these information in central databases. Furthermore, on the European level efforts to standardize resource information for disaster management are made (Henriques and Rego, 2008). But flood response specific resources are not yet included in them. Experiences from the extreme Elbe flood in 2002 have revealed severe deficiencies in resource management despite the described organisational structure and flood response plans. It was mentioned that sufficient information about resources and their availability was not available. Furthermore, the procedures of resource requests and allocations were unclear. These issues lead to resource allocations which are not transparent and increase the risk of idle vehicles, materials and equipment. As a consequence response operations highly risk to be delayed or may even fail. Beyond aspects concerning resource information also situational information as predicted inundated areas in terms of impassable roads can affect the delivery of resources. Therefore this information has also to be provided for efficient resource management. In order to face these problems and in order to improve future resource management, IT-methods are developed and applied in the scope of the research project "Process-based cooperative emergency management for water infrastructures". The next section shortly presents the overall approach of this project. Then the resource management support methods are illustrated in detail.

Process-based emergency management for flood response

The overall goal of the process-based emergency management for flood response is to support the control staff of the EOCs and the crisis units of public authorities in planning and managing response operations during extreme flood events.

Therefore, procedures for alerting, for flood defence operations and for resource ordering and allocation are analyzed and modelled as processes. These can be stored, started and executed within the process management system (see Figure 1).

Figure 1. Overview of process-based emergency management system for flood response



The responsible persons of the flood response organizations are provided with a web client interface which allows them to work on their process tasks. The system has interfaces to receive information about actual water levels from sensors and about predicted inundated areas from dike break simulations. This information is used to automatically trigger processes and for decision support. The use of process models allows for a structured, defined information flow between the different public authorities as well as to other flood response organizations. The system includes a resource database which provides necessary data for the resource management.

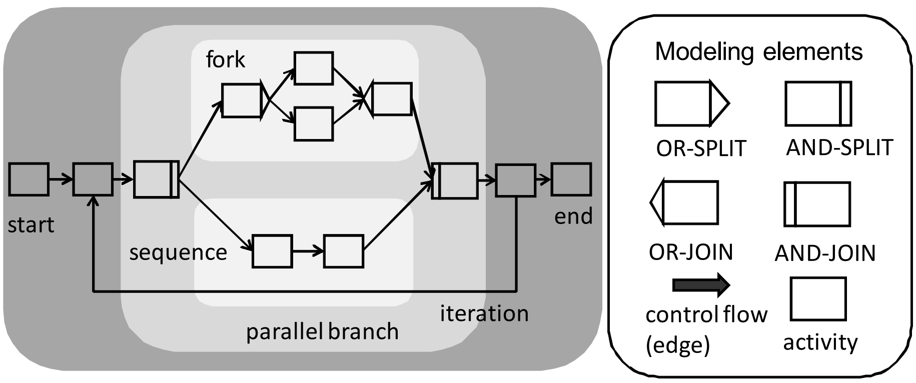
Resource management support combining process models and GIS methods

In the following subsections, the IT-methods and technologies are presented which shall support future resource management in flood response.

Process models and process management systems (PMS)

Process models allow to defining procedures where interdependent tasks shall be performed in a logical order by different persons and organizations, and where task related information has to be passed between the agents. The process models consist of activities which are logically ordered as sequences or in parallel, and have a start and an end point. An agent is assigned to each activity. The agent can be a concrete person but also a position in an organization (e.g., EOC staff member of a district). Processes can be modelled with process editor software using a formal notation so that the models can be executed, controlled and supervised with a process management system. The process models then serve as templates from which process instances can be generated and started. The process management system is running on a central server and provides a web client interface for agents. The agents perform their activities with this interface on their computer. If a process model is started the activities will be executed in the defined order. In this context an activity is a task which appears in the task list of the agent's web client interface at the time the precedent activity of the process is completed. Depending on the type of the PMS and its web client interface various types of activities are supported. An activity can be a text message the agent has to read and to confirm, an electronic form he has to fill in or an electronic map on which he as to choose a location. In principle, any program logic can be encapsulated in an activity. With PMS, it is furthermore possible to have activities in a process which are automatically performed by the system without user interaction. One example would be to send a system generated notification message through phone call software. In this research project the PMS Aristaflow (Dadam et al, 2007) is applied and customized, because it offers an excellent process model design support and allows to develop own process activity types. The notation for process model elements in Aristaflow is depicted in Figure 2.

Figure 2. Process model notation



Besides sequences it is also possible to model iteration loops and forks in the process flow. For each iteration or fork, a condition has to be defined which is checked when the process is running in order to decide to loop or rather to decide which branch to execute.

GIS methods and applications

In Aristaflow, own activity types have been developed to customize the PMS. Activity types for the integration of GIS methods and applications have been implemented, because geoinformation is essential for resource management support. Information about geographical locations of available resources and flood defence locations as well as predicted inundated areas, flooded streets and transportation routes allow for a more efficient resource allocation and offer advanced decision support. Therefore, this information is integrated in the process model for resource management (cf. following subsection). For the presentation of maps and map-related information a webGIS client is developed which has an interface to the process management system and can be integrated as process activity. The webGIS client interface has the following main features:

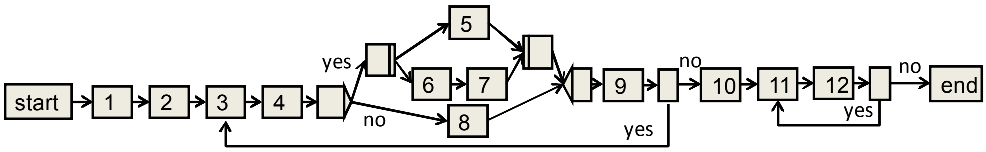
- Visualization of resource depots, flood defence locations, predicted inundated areas and transportation routes on a digital map
- Create and modify flood defence locations on the digital map
- Mark depots which have the requested resources fully or partly available
- Show endangered depots which are located in predicted inundated areas
- Show information about available resources (resource properties, quantities etc.)
- Depot and resource selection on the digital map
- Calculate distances and total transportation time from every depot with available resources to the place of operation considering potentially flooded streets

The webGIS receives over the internet up-to-date forecast information of dike break simulations by a developed module. The dike break simulations are calculated with the software FloodArea (Geomer GmbH, 2006) which can be running on a computer cluster to allow a fast simulation of dike break scenarios for operational purposes. Furthermore, ongoing implementations integrate the internet route calculation service “OpenLS route service” from Universität Bonn (Neis et al, 2007) in the webGIS to dynamically perform route calculations from potential resource depots to the flood defence location. This service also considers in its route calculation inundated areas which are impassable for vehicles.

Process model for resource requests and allocation

In order to achieve a more transparent and efficient resource management, resource request and allocation procedures are represented as a process model. It defines the information flow between the agents, provides important geographical information and handles resource requests and allocations. This process model with its activities and activity types is shown in Figure 3.

Figure 3. Resource management process model



Activity descriptions
A1: input of target location for resources
A2: input of needed resource types and quantities
A3: map with resource information (location, availability, distances etc.); choice of resources
A4: person in charge of requested resources decides over allocation (yes/no)
A5: resource requester is informed about successful allocation
A6: depot manager gets system generated phone message
A7: depot manager receives resource delivery information
A8: requester is informed about rejected resource request
A9: decision about new resource request (yes/no)
A10: confirmation of resource delivery
A11: return free resources after flood response operations
A12: check if there are still resources in use (yes/no)

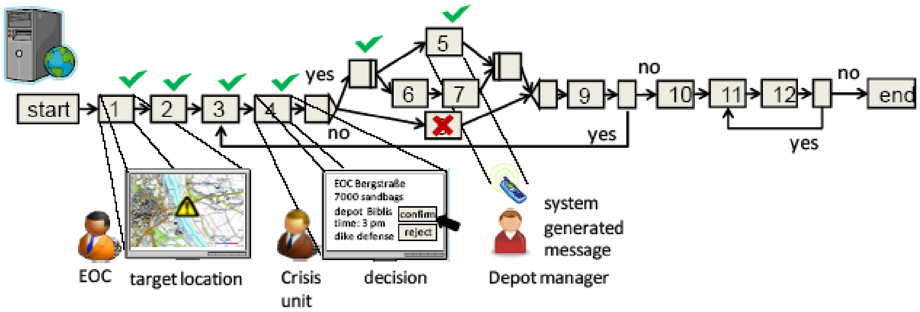
activity types
webGIS: A1, A3
imput user form: A2, A4, A9, A10, A11
information user form: A5, A7, A8
messaging software: A6
automatic database check: A12

A separate instance of this process model will be started each time an EOC member initiates a resource request (which may contain different types and quantities of resources). Then, activity 1 will start the webGIS client interface of the EOC member where he has to choose an existing target location or create a new target location for the resources.

In activity 2, a search form with a range of resource types will appear on the screen to let the EOC member choose types and enter quantities. Then activity 3 invokes the webGIS client interface and shows depots from the different organizations which have available resources and which do not risk to get inundated. Furthermore, information about distances and transportation times is provided. The EOC member can choose the needed resources on the digital map and can commit the resource request to the system. Depending on the responsibilities for the requested resources, the agent of the assigned organization will be informed and can confirm the resources or reject the request (activity 4) over the system. If he rejects the request the EOC member will be informed and may perform a new request (activities 8, 9) so that activity 3 is started again. If the agent allocates the requested resources, the requester will be informed (activity 5) and the depot manager gets a system generated phone message that a resource order arrived and that he shall log on to the system (activity 6). Then he can receive information about destination, time, quantity and type of ordered resources over his web client interface (activity 7). The delivery of the resources to the place of operation has to be confirmed (activity 10) by the depot manager. When the resources are not needed anymore for the operation the responsible person can commit that information to the system so that they become available again for other operations (activities 11, 12).

The activity types (see text in Figure 3) define which application context or program logic is associated with which activity of the process. For user interactions the activity types "webGIS" and "user form" are used. Examples for automatic activity types are database queries and the invocation of messaging software to send a system generated notification message. Figure 4 depicts an example of a process instance with some of the mentioned activity types. In this example activities 1 to 5 are finished. As the crisis unit member in activity 4 confirmed the resource request, activity 8 is skipped.

Figure 4. Process instance example

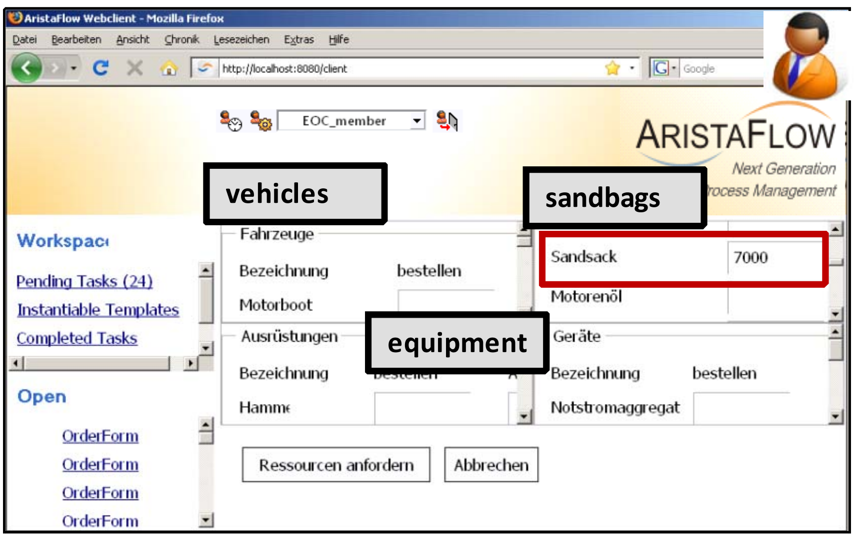


In the following section an application scenario is given in order to clarify the described resource management support with process models and GIS methods.

Application scenario

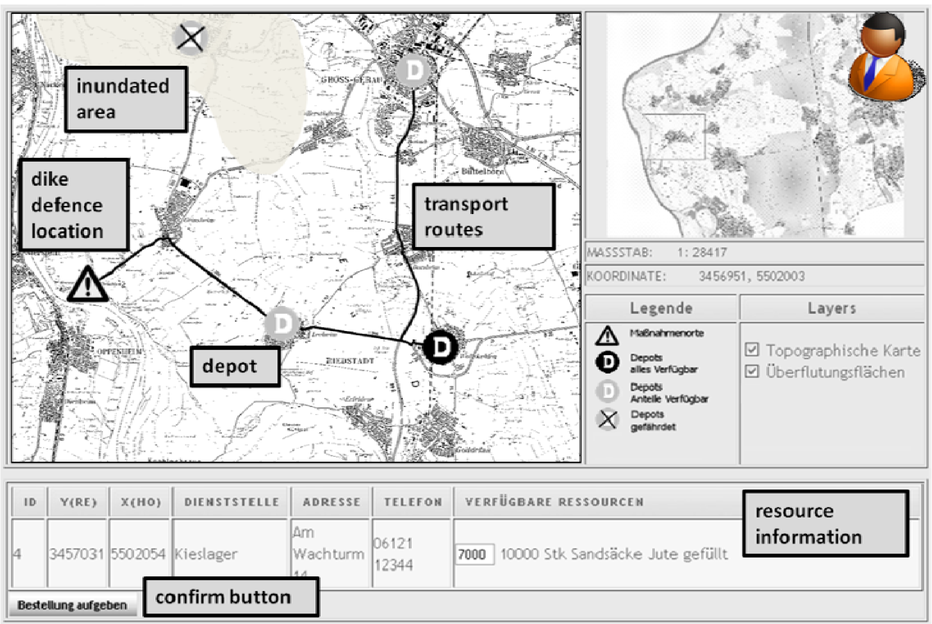
The western border of the German state Hesse is located at the Rhine River. The areas next to the Rhine are mostly protected with dikes against floods. Nevertheless, if an extreme flood event occurs, at some places the dikes may be over flown and older parts of the dikes risk breaking. Such an extreme flood event is assumed for this application scenario. During flood response the EOC of the district "Groß-Gerau" needs 7000 sandbags in two hours to build a wall of 200 metre length and 0.5 metre height at dike kilometre 15. The EOC staff starts an instance of the resource management process model with his web client interface and marks the target location on the digital map. In the next step he enters 7000 sandbags in the resource search form (see Figure 5).

Figure 5. Resource search form



The webGIS client interface is invoked and shows all depots which have the amount of sandbags available for the requested time (see Figure 6). Furthermore, information about the distances and transportation time to the dike location is presented and predicted inundated areas are visualized. It is shown in Figure 6 that there are not enough sandbags available at the nearest depot to the flood defence location (gray symbol). One depot risks to be in an inundated area at the time the resources are needed (crossed symbol). The direct route from the depot in the top-right corner to the target location is blocked by an inundated area. The nearest depot with at least 7000 sandbags is marked in black colour and the routes to the flood defence location are shown on the digital map. The agent may click on the depot symbol and further resource information will be shown at the bottom of the screen. He starts the request of 7000 sandbags of this depot by activating the confirm button. As the depot belongs to the neighbour district, the responsible person of the regional crisis unit in "Darmstadt" receives the resource request information and decides to supply the needed amount of sandbags. The remaining parts of the process follow the logic of the description in the previous section.

Figure 6. Resource selection with webGIS



Summary and Discussion

Extreme floods in the recent past have shown that requests and allocations of resources during flood response are not yet satisfactory. Insufficient information about resource locations and their availability has been observed in after crisis reports and resource ordering and allocation procedures were unclear despite the existence of flood response plans. For this reasons flood response operations risk to be delayed or may even fail.

In order to improve that situation, an IT-supported system for resource management with process models and GIS has been described in this paper. Resource request and allocation procedures which involve multiple response organizations are defined as "processes". Agents are provided with resource management tasks and related geo-information through a web-based process management system (PMS). The webGIS interface provides advanced support for resource selection, including the consideration of potentially flooded areas in transport route suggestions. This approach allows for transparent resource management procedures, guarantees a structured target-oriented information flow and therefore supports the flood response actors in their decisions and actions. The graphical user interface of the web client has further to be evaluated within small trainings for the EOC staff of the district which is involved in the research project. The overall approach requires a wider understanding of IT-supported process-oriented work in flood response. The system will be evaluated with experts in the near future.

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Author Biography

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Armin Wagenknecht holds a diploma in Civil Engineering and Management of Technische Universität Darmstadt. He is specialized in Process Modelling, Process Management Systems and GIS for emergency management and is currently working on his dissertation within the research project "Process-based cooperative emergency management for water infrastructures".