Mobile Internet GIS based Flood Warning and Information Systems

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Summary

The recent flood disasters showed that available warning systems do not fully fulfill their requirements and potentials. This paper examines these regarding web-based and mobile GIS based flood information and warning systems. We present first prototypes that are being developed at the University of Applied Sciences Mainz for a pilot area at the Rhine and give an outlook on the state of art and potentials for mobile disaster management systems. Environmental disasters are spatiotemporal events, so only GIS can fulfill the needs of the disaster management staff, e.g. updates of the spatial extent of the disaster wich must be made available very rapidly to all interested parties. We discuss the scenarios for a mobile flood warning system and give an overview of system architecture.

Introduction

Geo information systems are valuable and powerful tools for the collection, management and analysis of flood-relevant geoinformation. The crucial disadvantage of danger management systems such as PoldEvac or the dyke information system North-Rhine/Westphalia is that these are built as desktop solutions, therefore specialized systems, which run as isolated solutions only on a limited number of computers. The possibility to send the information and results of analysis of these systems rapidly and efficiently to a large number of users is missing. So if we postulate that distributed component based systems are a more suitable approach we have to discuss the scenarios in which these shall be used in order to derive the properties of such components.

Scenarios

We found the following main scenarios for a distributed gis-based disaster management system for floods:

1.) Prevention and Information

Awareness of potential risks through floods needs to be strengthend in order to minimize future impact. So dangered areas need to be clearly identifiable for citizens.

2.) Flood prediction and warning

Flood information systems need to integrate environmental data relevant for flood warnings (e.g. water levels, weather, thaw...) with existing forecast models (e.g. water level models) which need to be computed dynamically. In the case of an predicted or measured emergency, warnings need to be triggered on various media (SMS, PDA etc.).

3.) Flood and Crisis Management

In case of emergency crisis staffs, rescue forces and citizens not only need to receive information, but need also an information and planning platform e.g. in order to update data directly at the location.

Requirements and Architecture

These scenarios have to be mapped on requirements and a general system achitecture. As there are no standard solutions regarding the integration of heterogeneous data & services, the system needs remain open for further extension (functional, regional, technical). A distributed and component based architecture is necessary to realize the identified scenarios. A GIS-based disaster manamagent system (DMS) for floods needs to be realized on basis of a geodata infrastructure (GDI), communicating over Internet-protocolls. It is therefore possible from each computer on the Internet to enter the system. Based on that we identified the following top requirements with respect to disaster management systems:

- maximum robustness / high scalability
- decentralized architecture, open standards
- handling of geodata on mobile client
- integration of external data and simulation models
- support for heterogeneous terminals

State of the art of Warning and Disaster Management Systems

After having identified the scenarios and some first requirements (more details on the requirements of mobile geodatabases for disaster management can be found in Zipf and Leiner 2002), we hwill have a look at the current state of art of these kind of systems. Warning and crisis management systems for floods are offered by different companies more and more since the catastrophic flood in August 2002. In many cases these solutions are based on content management systems (CMS) and/or technologies, which were already offered for the area of project management and offered now under another name. However so far only few systems are tailored to the special requirements of a flood event. For example the systems HowISS (Flood Information and Protection System), used in Heidelberg, Cologne and Bad Friedrichshall for some years, supports in general the planning and execution of measures on basis of level forecasts with flood events.

The projects and systems within the area of flood protection cannot easily be combined to groups on the basis their services and applications. Nevertheless we try to give a rough overview:

1. *Automated collection and transmission of environmental data*
   Automated systems for the collection of current environmental information, e.g. the level measuring net of the HVZ equipped with long-distance data transmission or the satellite-based remote sensing systems of the DLR
2. *Environmental data bases*
   Systems for the input, collection and administration of environmental data data e.g. an environmental information system (UIS).
3. *Geographic Information Systems*
   Geographic Information Systems (GIS) take an intermediate position. On the one hand they manage the geodata by providing database functionalities, on the other hand they present the data in form of digital maps. As they also offer different analysis tools they also take over functions from systems for danger simulation (4.). Examples of GIS applications used in the range flood and/or danger warning are e.g. PoldEvac, DISMA, the dyke information system North-Rhine/Westphalia or the GIS Zurich.
4. *Systems for disaster/danger simulation*
   These are computer-aided models, which try a concrete danger situation to simulate and/or predict. If spatial processes are to be simulated, a GIS is always a component of such a system. In the case of FloodArea e.g. by proprietary programming for the GIS ArcView.

5. *Management systems*
   Such systems have to support the task of decision makers with their decisions. The system submits suggestions for actions which are triggered on the basis the received information (e.g. predicted water level) (e.g. HowiSS).
6. *Communication platforms*
   The task of a communication platform is to distribute the available base data, evaluations and simulations, forecasts, action plans, reports on the situation, recommendations or procedural instructions purposefully to the respective addressees. A communication platform is independent of the kind of data. For example the information generated with an outdated simulation model can be exchanged at any time with the information from an improved model.

While a GIS is only meaningfully usable, if the necessary data is implemented - which in practice is one of the largest problem after Dombrovsky 2001 - a communication platform is usable even in principle without background information. However the usability rises with the quality and completeness of the available data. The information can be distiributed over different media (e.g. Internet, phone, fax, SMS) depending upon the desires of the user. There are no communication platforms tailored to flood disasters availbale so far. Only in the research project OSIRIS first demonstrators for a such system have been developed. For an overview of the current state of the mobile geo information technology see [ZS02].

Earlier work

Already in our earlier projects we offered interactive inundation maps on historic flood events with further information. For example in the tourist information system Deep Map WebGIS [ZI00,02] it was possible for the interested user to request geographical information on Heidelberg, amongst others also flood maps and the appropriate aerial photographs. The system was based on a coupling of ArcView and ArcIMS and the flood information was found by database queries. The geo data originated from our own digitization of the flood areas on basis of airial photos taken during the floods. However there were no such things like prognosis models for flood, dynamic level inquiries or warning systems integrated in this system. First prototypes of the Deep map WebGIS consisted of an applet for representing an interactive map offering seamless zooming (fig. 1 [ZI02]). A special challenge of seamless zooming was - and still is with - a dynamic optimization of the map labeling and symbol placement, which had to be realized using extensive programming [ZK03]. On the map it was not only possible to click on objects of interest (to which information from the database then was presented), but vice versa various search functions allowed to search in the multimedia database. Result objects of the database search could be presented on the map using the function “Show on map”. While this is not new, the interesting thing is, that this applied not only to spatial objects (e.g. buildings), but also to e.g. events or persons because of a comprehensive and also indirect geocoding of such kinds of objects in the database [WE00].

Fig 1: Flood information in the Deep Map WebGIS – the flooded area of the Neckar in Heidelberg April 1994 (stripes) is presented as map layer, right hand the according aerial photo.

Web-based Flood Mapping - the example of the upper Rhine

Using the inundation surface model of [LE03], Web-Mapping applications are being developed at the University of Applied Sciences Mainz for the spreading by flood information for an pilot area on the northern upper Rhine. A goal of the project is the Internet-based spreading of interactive maps of the flood dynamics of the investigation area. This encloses besides empirical data of the flood dynamics and forecasts derived from these and geographical background information e.g. the change of the land use or settlement growth in the investigation area, and also areas with a high risk of inundation water. The extent of the inundations which can be expected can be predicted based on the water level forecasts of the flood forecast centre available online.

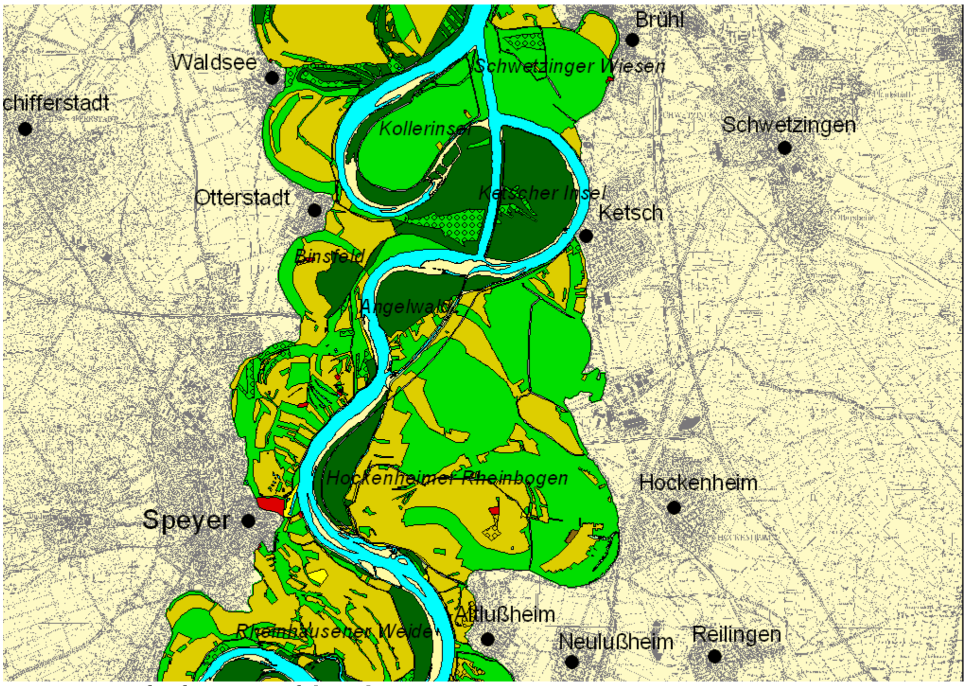

Fig 2: part of a first map of the pilot area

Studies on flood dynamics

For the section of the Rhine in question (fig. 2) there exist detailed investigations of the flood dynamics [KI02; LE03]). Based on inspections of the area and flights, water level measurements and soil probes the spatial and temporal change of the recent inundation surfaces from 1997 to 2001 was seized, mapped and documented additionally by photo and video. Furthermore aerial photographs were analysed, which were taken briefly during and/or after flood events of the 1970es and 1980es. Based on this information the extent of the inundations was simulated as a function of the water level at the level Speyer on the basis of a high precision DGHM [HI01]. Because of previous intense field work a lot of inundation maps were already present for a majority of the water levels and could be used for the calibration and/or adjustment of the model.

Special case of inundation water

During the flood of 1999 it became obvious that within landscape and town planning the problem of the pressure water has been neglected. The majority of the damage to buildings and harvest losses resulted not from a water spilling from the river, but from the underground swelling water (pressure water or „Qualmwasser") in the old river beds ("Altaue") protected allegedly by the main dam of the Rhine against inundations.

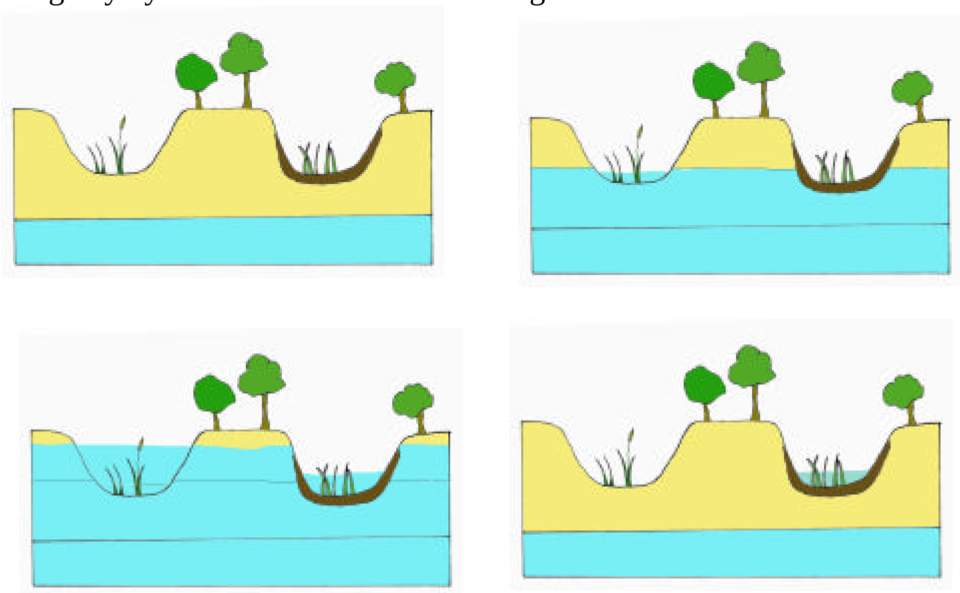

Fig 3: the process of inundation – causing floods without breaking of dams etc.

Since the models used far for the simulation of inundation surfaces care only for flow dynamics above the ground (e.g. FloodArea [AS03], and as there is nearly no data for a simulation of the underground flow processes (e.g. distribution of water-leading sediments, tight groundwater measuring net), pragmatic solutions were searched for, in order to make at least a rough estimation of the areas potentially endangered by pressure water.

So numerous inundation water surfaces could be identified by the interpretation of harvest damage in aerial photographs taken in shortly after flood events. Remarkably numerous of these areas have been cultivated and used for buildings meanwhile. Furthermore the historic Rhine Atlases of the "Großherzogtum Baden" have been geo-referenced and analyzed in a GIS [JA02; LE03]. Through that it became clear that the areas that have been used only extensively in 1856 because of the still higher ground-water level at that time correlate strongly with the current pressure water areas.

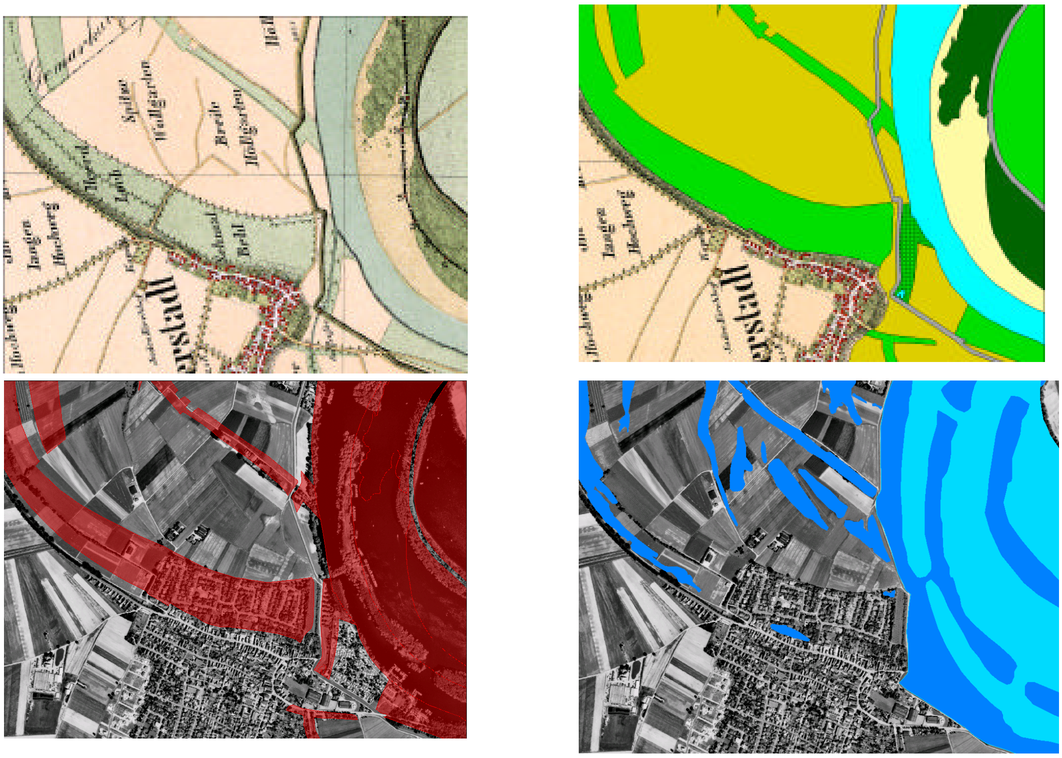

Fig 4: results from the analysis of historic maps (Rhine Atlas 1828, 1856, 1875) with recent flood areas and aerial photos (1999).

For the pilot area the following flood-relevant data could be generated and collected on basis of the study of the inundation dynamics discussed earlier:

- empirical, water level-referred inundation surface mapping
- digital terrain model (1:5000; TIN)
- flood areas simulations derived from the digital land model related to the level Speyer
- historical land use 1856 and 1875
- perpendicular aerial photographs (* img)
- aerial photographs and terrestrial aerial photographs
- measurement series of the development of the pressure water during the flood 1999

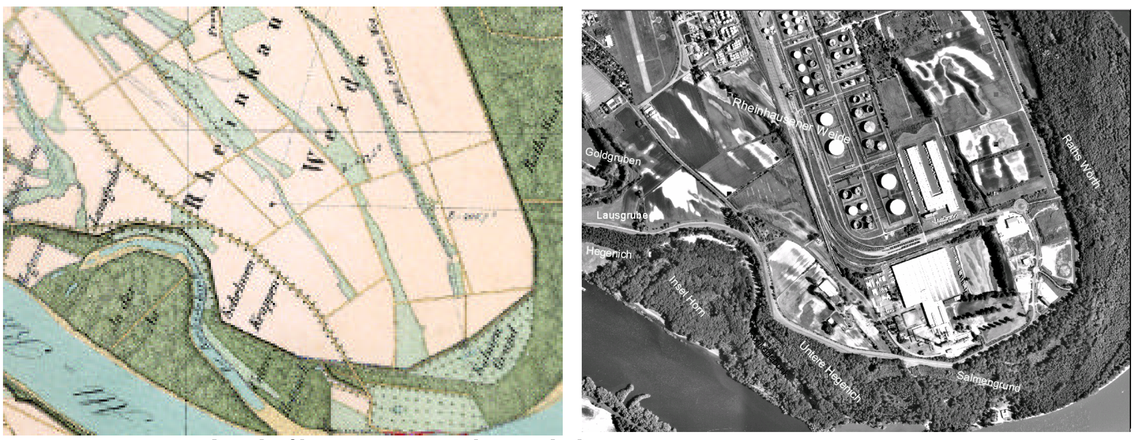

Fig5: comparison detail of historic map with aerial photo

Technology

A web map server (WMS) produces maps either as raster graphics, e.g. in the formats GIF, JPEG or png, or WBMP (WAP bit-map). Scalable Vector Graphics (SVG) is an increasingly used vector graphic format based on XML. In the project the open source map server of the University of Minnesota is used (UMN Web map server) [UM03] with his well-known features. Parallel in a current prototype for an on-line flood information system interactive vector maps on basis are tested using SVG. Beside SVG-plugins for the Web also first SVG browsers for mobile devices [e.g. BR02] are being developed.

Technologically there are meanwhile several practicable solutions for the development of WebGIS or Web Mapping for the Internet and Intranets. In order to improve the interoperability between the systems most of the necessary interfaces are standardized by the OGC. Beside commercial solutions one can use different free implementations (e.g. the deegree framework [DE 03] we used in another part of the project). The latter seem to be developed far enough today, in order to be used also in productive systems. While several products are called OGC conformant, there exist still obstacles for a genuine interoperability - among other things because of manufacturers heavy use of vendor specific parameters, which need to be used in the different products more or less obligatory in order to obtain reasonable result. But this make an exchange of the products more difficult [PA03].

Collection and Analysis of flood-relevant data

Apart from the access to dynamically updated environmental data important for the disaster management (e.g. ground water conditions and predictions, maps for current and predicted flooding areas, precipitation data) the decision maker need access during a flood event to a range of further information e.g. infrastructure data, locations of environmentally hazardous materials, partners and responsible persons at the task forces etc. Therefore it must be ensured that these information is coleected and prepared in databases and/or a GIS. A substantial component of the work of recent projects in the flood precaution dealt with the production and management of such flood-relevant data. For example in one of the earliest projects, PoldEvac, the focus of the German-Dutch project was put on the question, which information decision makers need at all. While the information technology used in that is out of date meanwhile, the final report of Dombrovsky (http://www.compuplan.nl/deutsch/pe indexd.htm) still gives valuable input. Similar a whole set of application-oriented research projects were started with the goal to improve the data situation in the case of crisis after the catastrophic flood of 1997. As a further example of such a typical GIS solution is the “Deichinformationssystem” NorthRhine-Westphalia.

User interface

In order to provide in a crisis situation a helpful and fast tool for the provision and transmission of information, the usage must be intuitively, simply understandable and reliable also for untrained users. In order to avoid faulty operations the usage must be straight and simple also in stress situations such as disasters. Different user roles with different information and requirements for interaction need to be differentiated: from the the citizen, headquarters and authorities to the rescue forces. Special attention is necessary on roviding a suitable cartographic representation of the spatial data frby means of maps [ZI02] optimized forf the substantial goals (tasks) of the user [ZH03].

From a user point of view the system consists of a public and a internal (i.e. password-protected) area. While the information of the public DMS is freely accessible for all citizens, the internal area is reserved to the closed communication between the authorities, crisis staffs and task forces. The internal part of the system hass to be restricted to authorized users. The different roles of the users (e.g. administrator, operator, crisis staff...) determine the range of the information and services made available (e.g. read and write rights) within the system. Furthermore the preferences of the individual user (e.g. the standard attitudes of maps and user interfaces) are stored in individual user profiles. For mobile terminals (Tablet PC, PDA handheld) these modules beed to be developed and adapted according to the special hard and software requirements of the devices.

Future Work: 3D digital terrain model

A 3D representation of the available DEM [HI01, LE03] with further geo data overlaid is planned (e.g. using vrml/X3D) for a future part of the project. However a dynamic production of the entire model as multi resolution TIN depending upon the to be visualized focus area as in [ZS03] appears as too complex for the first prototypes. In particular due to the extraordinary requirements in an emergency further work would be needed to support a better scaling. This still offers several interesting possibilities for subsequent research.

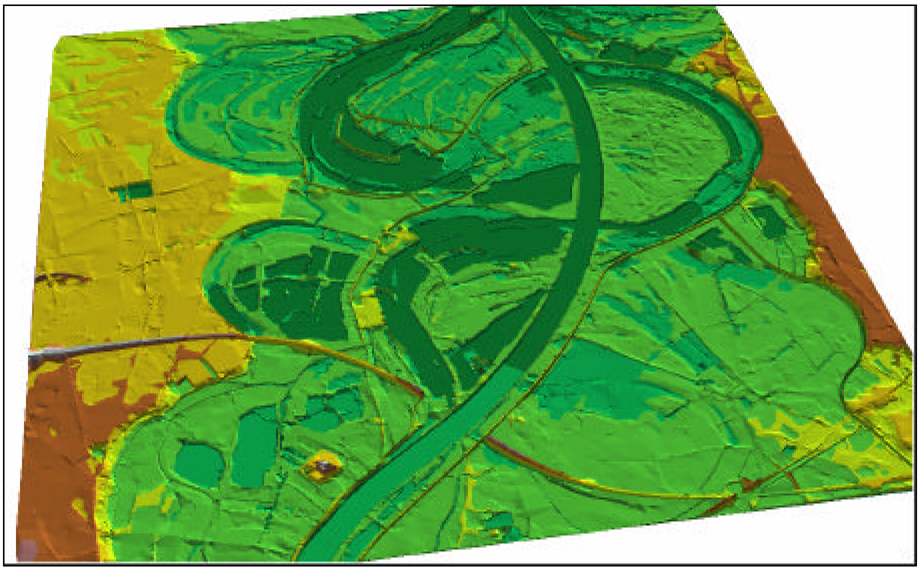

Fig 6: 2.5D digital terrain model of the pilot area

Client side vector-based 3D-worlds are still less well accepted and somewhat more complicated because of the necessary plugins or additional components like applets. A new standardisation suggestion of the OGC named Web terrain server (WTS) offers another possibility: the WTS is very similar to the concept of a WMS by offering the possibility to produce 3D-Views as raster graphics from 3D-GeoDaten, which can be represented then within usual WebBrowser. An appropriate reference implementation of [DE03] is planned as base for future realizations of such possibilities. This is in particular also for the transmission on mobile clients a promising and pragmatic basis.

Summary

Systems based on SDI (Spatial Data Infrastructures) admittedly offer large potential for communication, support with various tasks. On the one hand they offer gains in efficiency, on the other hand they offer new possibilities through the intensified integration with other distributed IT systems, which represented isolated applications before. Through the combination of dynamic forecast models with WebMapping and mobile devices a new quality within the range of the flood information systems is reached. The possibilities arising from mobile communication seem to offer at least the same - and in many cases quite larger – potential. But still the technology is not ccompletely accepted, not yet fully available and therefore the actual realization still has technical problems to solve [ZA03]. In order pick only one example, which concerns also our current work concerning the evaluation of SVG, e.g. still improved of compression algorithms of vector-based geo data are necessary in wireless nets, e.g. by [BE99, CE00, SH02]. See [CO02] for mobile 3D-maps. Another topic is the accuracy of the positioning e.g. in emergencies [ST02]. Within this paper we cold not touch the area of data and system security or privacy, which represents a fundamental aspect in particular with mobile solutions and positioning [HO02]. A further step regards the integration of up to date remote sensing data [PE03] into such systems (whether for Web or mobilely) for floods. With the presented map-based flood information systems we illuminate the potential of Web-based communication of new media and improved the availability of flood prognosis infromation for both the population and rescue workers.

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