Emergency mapping

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EMERGENCY MAPPING

Synonyms

Crisis Mapping

Definition

The term "*Emergency mapping*" refers to the creation and use of maps – paper or digital - before, during or after emergencies and disasters. While "*hazard and risk mapping*" is primarily used to visualize the hazards and risks during the pre-event phase, "*emergency mapping*" focuses on supporting response and relief efforts. Nevertheless, both types of maps are closely related to one another since hazard and risk maps can be included into emergency maps as important components. Nowadays "*Geographic(al) Information Systems*" (GIS) play a critical role in the development and use of these maps. GIS-based emergency maps are often an integral part of web-enabled crisis information management systems.

Introduction

Successful emergency management would not be possible without maps. Emergency maps visualize vital spatial information for planning and response through an easily understandable mean. One of the well known early examples of emergency maps is the mapping of the Cholera outbreak in London around 1850. During the Cholera outbreak Dr. John Snow plotted the observed Cholera deaths on a hand-drawn map. He realized that many deaths occurred in the immediate vicinity of a specific water pump. By examining this pump it became obvious that it drew polluted water from the sewage system. Dr. Snow simply recommended to remove the handle. The Cholera outbreak stopped soon afterwards (Snow, 1855). In the course of time emergency maps became more sophisticated and with the advent of Geographical Information System in the 1980s the creation of these maps and the analysis of emergency management related information became easier and more efficient. Nowadays emergency managers rely heavily on map products created before and after a disaster. Recent experiences during the response to the World Trade Center attacks (2001), the Indian Ocean tsunami (2004), Hurricane Katrina (2005), and the recent Haiti earthquake (2010) show that emergency maps were used very successfully (Committee on Planning for Catastrophe, 2007).

Categories of emergency maps

Up to now no overall accepted classification of emergency maps exists. One commonly used classification is based on the usage of the maps related to an incident. While some emergency maps are used prior to an incident (pre-emergency maps) others are used during the response to and recovery from an event (post-emergency maps). Both categories are discussed below in more detail.

Pre-event emergency maps

Pre-event emergency maps are typically used for emergency planning. They are integral part of emergency plans and are either publicly available or attached to planning documents of response agencies or high risk industrial facilities. The goal of pre-event maps is to improve speed and efficiency in case of an actual event as they provide guidelines on intended behavior or desired response activities. Pre-event emergency maps may exist for any type of possible incident, including evacuation of buildings and areas, large events or possible emergencies due to natural and technological hazards. They should be updated frequently and should reflect the most current information about the potential hazards and risks.

Evacuation maps are often included in public information materials related to possible threats, like building fire or industrial accidents. In many countries evacuation maps have to be highly visible in public use buildings, like hotels, shopping malls or stadiums. Goal of these maps is to provide guidance to best possible evacuation routes under the assumption that people are unfamiliar with the area and may be under stress.

Pre-emergency maps for large areas, like maps for accidents of nuclear power plants or snow emergency maps are mainly addressed to local residents. These maps have slightly different design requirements because people usually have a longer time available to familiarize themselves with the map. Different zones for different alert levels are frequently used in these large-scale maps (e.g. evacuation zones for storm surges).

Pre-event maps addressed to responders serve a different purpose and dependent on the domain. These maps may include information about locations of possible response resources, detailed hazard and risk maps, and detailed estimates for possible event scenarios.

Post-event emergency maps

Although post-event emergency maps are sometimes created to guide and support the affected population, emergency managers are the key users of this type of maps. Post-event maps are used to support any kind of emergency management function. Among others, some of the most critical functions using emergency maps include:

- Damage and needs assessment
- Emergency logistics and resource tracking
- Mass care and shelter
- Search and Rescue
- Fire Fighting
- Health and medical
- Evacuation
- Hazardous material response
- Forecasts (e.g. storm and plume modeling)
- Public safety and security support, including crowd control
- Critical infrastructure repair and recovery

While each function has its own relevant map data and design requirements the common denominator is that the maps are used in time-critical decision environments. Therefore these maps are created to answer one or more operational questions through visual representation of key information.

Symbology

Like on any other map, symbols are essential components of emergency maps. Symbols are abstract graphical objects used for the representation of natural or artificial features. Although the use of self-developed sets of emergency symbols is still very common among response organizations several standardization approaches try to create a set of standard cartographic symbols. Main goal of these initiatives is to facilitate information sharing between involved response agencies. One of these standards is the U.S. Homeland Security Mapping Standard (ANSI/INCITS, 2006). It includes a set of common symbols for different types of incidents and natural events, infrastructures and operational data. In Germany the responding organizations use a standardized set of tactical symbols (SKK, 2003). In Netherlands a set of symbols was designed for emergency response sector (Heide and Hullenaar, 2007). Some of these symbols, especially for resources, can be rather complex since they include information about organizational affiliation, resource type, unit size, direction and time.

Geospatial Data Needs

The information needed for emergency response can be grouped into two large clusters, dynamic information (situational and operational) and static (existing) information. Data collected during a disaster are denoted as dynamic data, while the information existing prior the disaster is named static information. Static information provides also the basis for pre-event emergency maps. For both categories the collected information can either apply to all hazards or it is specific to a single hazard or type of event. Typical information needs are for example published in (Board on Natural Disasters, 1999) or (U.S. DHS et al., 2008).

Some examples of dynamic information are:

- Incident: location, nature, scale
- Effects / consequences: affected and threatened area, predictive modeling results
- Damages: damaged objects, damaged infrastructure
- Casualties: dead, injured, missing and trapped people and animals
- Accessibility: building entrances, in- and out-routes, traffic direction, blocked roads
- Temporary centers: places for accommodating people (and animals), relief centers, morgues
- Meteorological information: wind direction, humidity, temperature
- Remote sensing imagery of the affected area
- Up-to-date data about involved response personnel and resources

- Hazard specific information: e.g. in case of flood – velocity and water depth, flood pattern

The most commonly used static (existing) information used for emergency maps includes

- Reference data: topographic maps, aerial photographs (orthophoto images), satellite images, cadastral maps and data
- Managerial and administrative data: census data, administrative borders, risk objects (gas stations, storage places of dangerous goods, etc.), vulnerable objects (schools, nursing homes, etc.)
- Infrastructure: road network, water network, utility networks (gas, water, electricity), parking lots, dykes, etc.
- Buildings catalogues: high/low-rise, material, number of floors, usage (residential, industrial), presence of hazardous materials, owners, cables and pipes, etc.;
- Accessibility maps: for buildings, industrial terrains, etc.,
- Locations of pre-planned resources
- Planned evacuation routes and shelters
- Water sources: fire hydrants, uncovered water, drilled water well, capacity, etc.
- Hazard-specific information: Hazard and risk maps, calculated event scenarios

Existing data is usually available from a variety of sources, including local authorities, national mapping agencies, cadastre, and private companies.

Emergency mapping and remote sensing

In emergency mapping the use of sensors is very important for collecting dynamic data before and shortly after a disaster. The information derived from sensor products is critical for monitoring the natural hazard and ensuring a better situational and operational awareness.

Remote sensing refers to the entire suite of sensors that allow the collection of data from various platforms. Relevant sensors (optical, thermal, range, radar, acoustic, temperature, water level, humidity, etc.) can be deployed on the ground, in the air, or in space. Some sensors (e.g. water level gauges, seismic, air quality sensors, etc.) can be mounted on stationary platforms (near rivers, volcanoes, chemical and nuclear plants) while others (optical, thermal, acoustic, range, etc.) are often mounted on moving platforms (satellites, aircrafts, helicopters, unmanned aerial vehicles, cars, etc.). To be able to estimate which technology is appropriate for a specific disaster a number of technical, cost and usability aspects have to be considered. Some of the most important technical aspects related to emergency maps are spatial resolution, spatial coverage and deployment time (Kerle et al. 2008). Examples of usability factors include:

- Availability of software for data processing: For example, software packages for raster image processing are widely available for all major GIS systems while software for laser scanner data processing is still subject to extensive research.

- Required expertise: Some products such as images (satellite or airborne) and videos do not require a specific expertise and can easily be used. However, many products are either not human-readable or require processing to derive the needed information. Expert knowledge may be required for the interpretation of this data.
- Required post processing time: Some products like image classifications, feature extraction, creating of digital terrain models, and creation of damage assessment maps can require days or even weeks.
- Sensor suitability for different emergencies: Different sensors have strengths for different emergencies: radar sensors are appropriate for mapping flooded areas, damage detection, land subsidence; laser scanners are useful for mapping emergencies with height differences before and after an event; thermal and infrared images are appropriate for fire monitoring.

Sensors and their products can also be used simultaneously. The integration requires geo-referencing to one predefined coordinate reference system. For example, using frequent snapshots from several sensors contributed greatly to the emergency response following the World Trade Center collapse (Rodarmel et al., 2002). For comparative analyses before and after a disaster, sensor products are regularly overlaid with existing maps and imagery. Examples for large-scale disasters like the Indian Ocean tsunami and Hurricane Katrina are published for example by Brecht (2008) and Kevany (2008).

Interaction with emergency maps and Visual Analytics

Many classifications for interactions with digital maps exist, but most commonly they can be grouped in:

- Animation / video,
- interaction (navigate, zoom, manipulate),
- query (explore),
- feedback and
- change (edit).

Amongst all the interactions emergency mapping benefits greatly from animation, query and change/edit.

Animation is a dynamic visualization of a series of images. The images can be snapshots of an area (or a specific object of the area) with different timestamps or a walk-through / fly-over of a given area. While the first technique is used mostly for the simulation of hazardous events, the second is used for orientation, path finding and navigation. Although visually ‘dynamic’, the user can only observe, but not change the sequence of visualized materials. Video-recording falls in the same group due to the same characteristics. Animations are widely used to represent expected flooded areas, plume spread, forest fires or tsunamis. For example, Jern et al (2010) describe how animations can be applied as final visualization technique in different stages of flood management.

Querying objects allows the user to obtain additional information about an object on the map or information about new maps. The additional information can be simple text, explaining a characteristic, or the query may execute an animation or voice recording. All major Geographic Information Systems allow for rather complex querying including selection by location or by attribute (e.g buffer analysis) or spatial joins and relates.

Change (edit) is the highest level of interaction. It allows users to invoke changes in the shape of an object or its attributes. This is usually the most critical functionality for a successful collaboration during emergencies. The editing could either be temporal (to explore different options) or permanent (persistently recording the changes in the map). Many of the emergency response systems developed in the last years large rely on such change/edit functionalities (e.g. Eagle One, Multiteam in the Netherlands).

Visual Analytics is yet another emerging technology, which is defined as the science of analytical reasoning facilitated by interactive visual interfaces (Adrienko and Adrienko 2005, Thomas and Cook 2005). Visual Analytics introduces a new level of indigence in the visualization, by finding specific patterns in a data set or after integration with other portions of information. Visual Analytics can be seen as fusion of visualization techniques with other areas such as data mining, databases and spatial analysis. Advanced emergency response systems apply Visual Analytics to support the decision making process. Examples are published by Todin et al. (2004) and Jern et al. (2010).

Innovative systems for emergency mapping

In the past many systems for emergency mapping of different disasters have been developed as specialized centralized systems (e.g. desktop systems) in which the data are available in a single repository (Amdabl, 2001, Greene 2002). In centralized systems data are constantly accessible; however, they might be easily outdated and due to proprietary data formats the integration of new data sets might be problematic. Related to centralized systems is the notion of scenario-based systems, in which complex models can be used to create realistic predictions and simulations.

In contrast, distributed systems rely on access and integration of data from different repositories. Since emergency mapping is highly dependant on the dynamics of the disaster, it is difficult to predict which information is actually needed in a specific situation. Generally emergency mapping has to fulfill two premises: (1) ensure supply of sufficient data from the field and (2) discover, access and fetch the most appropriate data from existing information sources. Consequently, emergency mapping can be also seen as an on-demand system. One of the main challenges of on-demand systems is the design and implementation of well-defined standardized services for discovery and exchange of existing information. Such services are closely related to the development of a Spatial Information Infrastructure (SII) for local, regional, national and international levels. As of 2010 a number of SII-initiatives are in progress worldwide, including INSPIRE in Europe (www.ec-gis.org/inspire). Those initiatives are further enriched with specific services for the emergency management sector. Large international projects like ORCHESTRA (www.eu-orchestra.org), OASIS (www.oasis-fp6.org) and WIN (www.win-eu.org) are already reporting results of their research.

Most of the technology that is required for access and exchange of 2D spatial information is available as implementation standards (e.g. WFS, WMS, WCS, WPS, WCPS, OpenLS, SFS, and GML), or as concepts (e.g. OGC Abstract specifications for open distributed management of geographical imagery, GeoRSS). Many extensions of existing standards are proposed for further discussions and new have been now also developed for 3D (CityGML, Web3D Service). The third dimension is considered also with respect to indoor modeling and integration with Building Information Models (BIM) for evacuation and navigation (Lapierre and Cote, 2008, Lee 2007).

Systems for emergency mapping has been traditionally developed by and for specialists involved in relief operations. However, experiences from recent disasters have clearly shown that information provided by local citizens and volunteers could be of great help especially in the first critical hours. For example Google Map, Open Street map, MS Bing Maps have been successfully used in Afghanistan, Pakistan, Haiti to share logistical and recue information. Although many open issues (reliability, security, accuracy, etc.), such technologies should be further investigated and developed.

Conclusions

Emergency maps are an essential component of effective emergency management during planning, response and recovery. Obtaining the best possible information about potential or ongoing emergencies is vital for emergency managers and the involved public. Since access to a disaster area is frequently limited the use of remote sensing technologies is often the primary way to receive initial information about the affected area, but the applicability of different sensor technologies and platform often depends on the actual type event. Collected data can be integrated, manipulated and analyzed via GIS and other related systems. Because of the complexity resulting from data diversity, sophisticated analysis tools and due to the involvement of multiple stakeholders, new approaches for collaboration using emergency maps are currently being developed. Although the research in this field is still very young, recent disasters proof the value of the integration of emergency maps with distributed, collaborative systems.

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Cross-references

Airphoto and satellite imagery in the study of natural hazards, applications
Disaster relief
Emergency management
Geographic information systems (GIS) and natural hazards
Geographical information system
Hazard and risk mapping
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Remote sensing of natural hazards and disasters