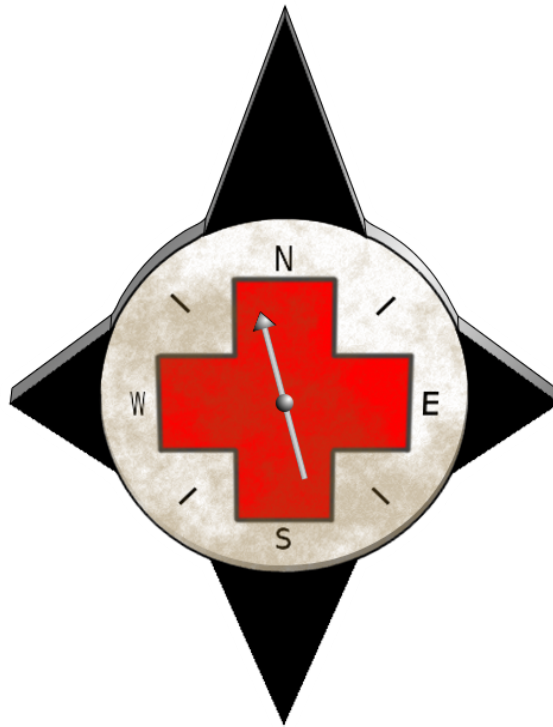


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Development of an Open-Source Mobile Application for Emergency Data Collection



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2014
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Development of an Open-Source Mobile Application for Emergency Data Collection

Master Degree Thesis, 30 credits, in *Geomatics*

Department of Physical Geography and Ecosystem Science, Lund University

Development of an Open-Source Mobile Application for Emergency Data Collection

Mattias Spångmyr

Master Degree Thesis in Geomatics, 30 credits

January 2014

Supervisors:

Ali Mansourian, Lund University

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Department of Physical Geography and Ecosystem Science
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Abstract

Mattias Spångmyr

Development of an Open-Source Mobile Application for Emergency Data Collection

This Master degree project identified disasters and emergencies as a global humanitarian and technological challenge. Emergency management organizations' need for access to accurate and up-to-date information about the emergency situation, to help respond to, recover from and mitigate the effects of disasters and emergencies, present a challenge to the field of Geomatics.

Today the use of remote sensing technologies presents an increasing number of solutions. There are types of spatial data, however, e.g. submerged, non-visual or otherwise hidden features that still require emergency field personnel and volunteers to interpret and record. By utilizing the increasing ubiquity and computational power of modern smartphones, in order to reach a large number of potential users and volunteers, a mobile application for emergency field data collection was developed. It was developed as a component of a system that, in order to be as collaborative, adaptable and accessible as possible, also to resource-poor organizations, was, with a minor exception, completely open-source licensed.

Field trials were held that, due to low participation, could not conclusively evaluate the application and its general applicability to emergency field data collection. They did, however, provide an adequate proof-of-concept and showed that it was possible to apply the application and the implemented system to a specific emergency field data collection task.

The system has great collaborative potential, achieved through openness, mobility, standards compliance, multi-source capability and adaptability. Its administrators are given a high degree of control that lets them adapt the system to suit the current users and situation and its flexibility make it widely applicable, not only for emergency management.

From literature, the field trials and the experience gained while developing and using the application, some ideas for improving the application and the system were discussed and some future research topics were suggested.

Keywords: Physical Geography and Ecosystem Analysis, Geomatics, Mobile Application, Development, Emergency, Data Collection, GIS, Android, Open-Source.

Supervisors: **Ali Mansourian** and **Per-Ola Olsson**.

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Dictionary and Abbreviations

API	Application Programming Interface; can be described as a group of pre-constructed software components that developers can combine and use for creating new software. A collection of algorithms, classes and/or data structures for e.g. performing specific tasks or communicating with other software.
DescribeFeatureType request	A type of request standard published by OGC (2013) and used by WFS clients to retrieve information about a specific layer offered by the WFS.
EDCA	The Android application developed as a case study during this thesis project; "the Emergency Data Collector for Android™".
EOC	Emergency Operation Centre, a location where emergency management leadership can gather to receive and analyse information, including spatial data, and coordinate rescue and relief efforts (Cutter 2003).
GetCapabilities request	A type of request standard published by OGC (2013) and that is sent to WMS or WFS services to query the service for available layers, options and capabilities in general.
GetMap request	A type of request standard by OGC (2013) that is used for requesting map images from a WMS.
GIS	Geographic Information System; a system capable of managing and using spatial data, aiding in activities such as data collection and storage, viewing, map creation, manipulation and analysis.
GML	Geography Markup Language, a spatial data standard published by OGC (2013). For further description see Table 3.
GPS	The Global Positioning System; a system of satellites that broadcast signals which allow devices with GPS receivers to calculate their position on the Earth.
Layer	A layer is a digital representation of a collection of physical features, such as roads, buildings, lakes etc. Each layer consists of a specific geometric type such as a Point, Line or Polygon and has common attributes, such as road length, building use category or lake area. A layer can be displayed on a map e.g. by querying a geospatial server.
OGC	Open Geospatial Consortium; a consortium of government agencies, universities and companies that develop common open standards promoting geographic information accessibility and interoperability (OGC 2013).

Open-source	Refers to computer software for which the license includes a number of access and use rights to its source code, defined by the Open Source Initiative (OSI 2013). That is, users may for example look under-the-hood of the program, modify it for any purpose and forward it to other users directly.
OS	Operating System; a basic device software that manages communication with the device's hardware and acts as a platform for managing and interacting with all other applications on the device.
Server	Refers to a geospatial server, see Figure 3, whose address can be stored in EDCA. It is a computer software system which can be sent queries over the Internet, in this case for geographic information to display on top of Google Maps, and to which data can be uploaded.
SFS	Simple Features Specification; a spatial data standard published by OGC (2013). For further description see Table 3.
SLD	Styled Layer Descriptor, an OGC (2013) web map styling standard. For further description see Table 3.
Smartphone	A hand-held device for mobile voice-, text- and data communication that has a fast Internet connection multiple sensors, including camera and GPS receiver. Its hardware is powerful enough to browse web pages and run advanced computer programs (mobile applications). Often uses large (for hand-held phones) touch-screens.
Spatial data	Data with a spatial component, i.e. coordinates, that are defined by an SRS and that bind the data to physical locations or geometric features.
SRS	Spatial Reference System; a system defining how coordinates relate to locations on Earth.
WFS	Web Feature Service, an OGC (2013) web mapping interface standard for serving geographic features. For further description see Table 3.
WMS	Web Map Service, an OGC (2013) web mapping interface standard for serving map images. For further description see Table 3.

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1. Introduction

Since 1980, 2.3 million people have lost their lives in the 21 000 events recorded in “the most comprehensive source of natural catastrophe data in the world” (Munich Re 2013a, p. 49). Total global material value lost due to natural disasters during the period is estimated at 3800 thousand million US\$, with a distinctly rising trend both in the annual rate of loss (Neumayer and Barthel 2011) and the annual frequency of reported natural disasters. In addition, technological disasters (e.g. industrial or transport accidents) contributed with on average 9000 deaths per year during the last decade, 2002-2011 (IFRC 2012).

With the increasing frequency of disastrous natural events and the expected increase in population and value in the world's cities (e.g. Bouwer et al. 2007; UNFPA 2007), often occurring in sensitive areas, societies are taking measures to prevent and mitigate the effects of such events (e.g. Godschalk 2003; Frazier et al. 2013). One facet of mitigation is about being prepared and much research is aimed at improving the preparedness of societies through developing better emergency management (e.g. Cai 2005; Al-Khudhairy 2010). Improving emergency management involves training personnel and developing tools and strategies used by emergency organizations for responding to and recovering from disasters.

One tool for improving emergency management is quick access to accurate and updated information about the emergency situation or disaster. Such information can be of vital importance for emergency management to enable distribution of the right resources to the right places at the right times and for prioritizing the efforts which have the greatest benefit. Much of this essential information has a spatial component, such as extents and locations of damaged areas, the locations of resources and services or safe transportation routes. Such geographic information, or *spatial data*, are useful in all phases of emergency management (Cutter 2003; Al-Khudhairy 2010).

There are, however, challenges to overcome in the utilization of spatial data and geographic information systems (GIS) in the context of emergency management, as recognized by e.g. Zerger and Smith (2003) and Mansourian (2005). One such challenge is providing decision makers and field workers with access to data that are accurate and sufficiently up-to-date for their specific purpose.

For data that cannot be captured with remote sensing techniques, such as satellite data and aerial photos, or stationary monitoring networks (see e.g. Liang et al. 2005), emergency management organizations have to rely on field data collection by employees and/or volunteers. As pointed out by EL-Gamily et al. (2010), recent improvements in software and hardware technology have enabled real-time access to and collection of spatial data in the field. However, supplying field workers with mobile GIS devices and education on field data collection can be expensive and time-consuming. This potentially limits the number of field data collectors that an organization can deploy in response to an emergency situation.

Many groups have utilized the increasing ubiquity and capabilities of modern

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smartphones for developing field data collection systems (e.g. Aanensen et al. 2009; Clark et al. 2010; Xu et al. 2010; White et al. 2011; Chen et al. 2012; Dezani et al. 2012; Weng et al. 2012). Several of these groups have developed such systems as open-source projects, which can potentially benefit society in terms of supporting collaboration between developers, allowing derivative work to build upon previous achievements and allowing less resource-strong communities access to these useful data collection tools.

This project builds on these notions of open access and collaboration in creating a free and open mobile GIS and field data collection system. A system that is tailored toward emergency management and has a high degree of scalability and adaptability to organization-specific needs. It makes use of existing open-source technologies for the server-side architecture and for the development of a mobile application, henceforth known as EDCA (the Emergency Data Collector for Android™), also released as open-source. As the system client, EDCA enables any organization or individual to – free-of-charge – set up a complete and customizable emergency field data collection system. It has the potential for rapidly engaging and providing spatial information and analysis to large numbers of field workers, who are increasingly already owners of compatible smartphones. It only requires distribution of EDCA and the server address to those devices.

1.1. Aim

The main aim of this thesis project is *to develop a mobile application as a component of a complete open-source system for emergency field data collection*. A secondary aim is to evaluate the mobile application to discern whether it is applicable to emergency field data collection and how it can be improved for that purpose.

2. Background

This chapter describes the context in which EDCA may operate* and why it is useful. By defining and describing disasters, emergencies and emergency management, and by outlining the role of spatial data in emergency management, the rationale behind its development is illustrated.

Furthermore, a brief study of the field of mobile GIS and field data collection is undertaken and examples of the technology, standards and open-source licenses available to it are presented. This will provide background for discussion about and aid in the development of the proposed system architecture and the implementation of EDCA that is presented in the System Design and Case Study chapters.

The United Nations Office for Disaster Risk Reduction (UNISDR) is developing a body of terminology for use by the emergency and disaster management communities. It is intended to improve the work to reduce disaster risk by making the use and

* DISCLAIMER: Any mention in this chapter of specific brands, products or software is solely for the purpose of providing examples to enable discussion and does not signify any affiliation with or recommendation by the author. Nor is it within the scope of this project to make a complete listing of all available alternatives.

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understanding of common vocabulary consistent throughout the community (UNISDR 2009). To help promote this common understanding this report will, where applicable, use the definitions proposed by the UNISDR.

2.1. Disasters & Emergencies

To understand the importance of emergency management and the environment in which EDCA and the proposed system (see section 3.2.) could be utilized, the nature and frequency of disasters needs some attention. The following definition of “disaster” is proposed by the UNISDR:

“A serious disruption of the functioning of a community or a society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources.”

– UNISDR 2009, p. 9

To study disasters, there are several database projects that record disasters and related information. Some of these databases are created and managed by re-insurance companies (e.g. Munich-Re and Swiss-Re). Since these companies provide insurances for other insurance providers, when disastrous events cause widespread damage, they are often paying a significant part of the recovery costs. Thus, in addition to e.g. universities and governmental organizations, these re-insurance companies have a natural interest in studying disasters and emergency management.

The definition of disaster above is used by Munich Re's natural catastrophe database to classify the most severe level of natural catastrophes; “great disaster” (Munich Re 2013b). Smaller events where the local community does not necessarily require external assistance are also recorded by major catastrophe databases. The smallest event class recorded by Munich Re is “small-scale loss event” which includes events causing “small-scale property damage” or one to nine fatalities (Munich Re 2013b). In the EM-DAT database, managed by the Centre for Research on the Epidemiology of Disasters (CRED) of the Catholic University of Louvain, Belgium, events are recorded if they cause either of the following (IFRC 2012, p. 251):

- *“Ten or more people reported killed”*
- *“100 people or more reported affected”*
- *“Declaration of a state of emergency”*
- *“Call for international assistance.”*

For the purpose of this report, “disaster” will be used according to the definition by UNISDR presented above. “Emergency” and “catastrophe”, on the other hand, will be used interchangeably and more loosely, and may include small events such as those recorded by major catastrophe databases as well as disasters. Emergency field data collection and mobile GIS can still have a role to play in emergencies that are handled locally (see e.g. EL-Gamily et al., 2010), so small-scale emergencies should also be

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considered within the scope of this project.

In 2007, Munich Re, CRED, Swiss Re, the United Nations Development Programme (UNDP), the Asian Disaster Reduction Centre (ADRC) and the UNISDR all communed to standardize the terminology used for describing and categorizing catastrophes (IFRC 2012; Munich Re 2013c). They agreed on a system based on two major categories – natural and technological catastrophes – which are in turn subdivided into five and three categories, respectively. These, in turn, have one or two sub-levels, further specifying the type of event (Table 1).

The events presented in Table 1 are categorized based on their cause, e.g. separating landslides or avalanches based on if they were initiated by geophysical or hydrological processes. While this is a relevant categorization for preparedness and mitigation, from a post-event emergency management perspective it can be argued that the effects are more relevant than the cause. Regardless, non-natural and non-accidental emergency events can occur that may require similar activation of emergency management organizations for response and recovery. Such events can include e.g. armed conflicts (wars, violent protests etc.) or acts of terrorism (bombings, sabotage, release of chemical or biological contaminants etc.).

Table 1: Catastrophe categorization developed jointly by Munich Re, CRED, Swiss Re, the United Nations Development Programme (UNDP), the Asian Disaster Reduction Centre (ADRC) and the United Nations Office for Disaster Risk Reduction (UNISDR) in 2007. Source: IFRC 2012, p. 251-252.

Natural disasters	Biological disasters	Insect infestations, epidemics and animal attacks.
	Geophysical disasters	Earthquakes and tsunamis, volcanic eruptions and dry mass movements (avalanches, landslides, rockfalls and subsidence of geophysical origin).
	Climatological disasters	Droughts (with associated food insecurities), extreme temperatures and wildfires.
	Hydrological disasters	Floods (including waves and surges) and wet mass movements (avalanches, landslides, rockfalls and subsidence of hydrological origin).
	Meteorological disasters	Storms (divided into nine sub-categories).
Technological disasters	Industrial accidents	Chemical spills, collapse of industrial infrastructure, explosions, fires, gas leaks, poisoning and radiation.
	Transportation accidents	Transportation by air, rail, road or water.
	Miscellaneous accidents	Collapse of domestic or non-industrial structures, explosions and fires.

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Natural catastrophes are by far the most common and the most costly type of event, both in human and economic losses. According to the EM-DAT database, during 2002-2011 (not counting non-natural, non-accidental events), natural catastrophes caused almost 13 times as many deaths as technological causes and in excess of 37 times as much economic damage (IFRC 2012).

Among the types of natural catastrophes, in all parts of the world meteorological and hydrological catastrophes are the most numerous (Munich Re 2013a). When it comes to fatalities, however, most are caused by geophysical events or, as in Europe and Africa, climatological events.

Asia, being the largest and most populated region, suffers the largest number of catastrophes, the most fatalities and the highest amount of overall economic losses, while North America alone has 65 % of the world's insured losses (Munich Re 2013a).

In recent years, current and future changes in the global climate have been projected to cause meteorological, hydrological and climatological extreme events to become more frequent or more intense in many areas (Parry et al. 2007) and an increase in the number of, as well as losses from, weather-related disasters have been identified (Bouwer et al. 2007; Neumayer and Barthel 2011). However, as the work by Neumayer and Barthel (2011) shows, it is not yet clear whether climate change has caused any increase in losses. It may be, as argued by Bouwer et al. (2007), that it's mainly the increased susceptibility of human societies that is causing current increases in losses, due to expansion of settlements into sensitive areas and further urbanization leading to a concentration of population and wealth at risk.

In any case, the need for better resilience to catastrophic events in human societies is increasing, and significant efforts to improve emergency management before, during and after an emergency event are being made.

2.2. Emergency Management

EDCA and the proposed system for which it is designed are intended to be used for emergency management, which incorporates all aspects of how communities handle emergency situations. It involves risk assessments as well as planning and education for improved preparedness. It involves policies, guidelines and routines for how to organize participants and resources available, to best respond to the events themselves and for recovering efficiently in the hours, days, months and perhaps years after an event. It also involves how communities learn from mistakes and take steps to reduce future susceptibility to similar events. More succinctly put emergency management is:

“The organization and management of resources and responsibilities for addressing all aspects of emergencies, in particular preparedness, response and initial recovery steps.”

– UNISDR 2009, p. 13

In what form emergency management is used depends on the type of emergency that is being considered, but different strategies may be more or less general in their applicability to different types of events (see Table 1).

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The different phases of emergency management are commonly described as forming a cycle (Figure 1; Cutter 2003; Mansourian 2005; EL-Gamily et al. 2010) with some form of categorization of the relevant emergency management activities. Figure 1 depicts one such interpretation using three phases based on the definitions below.

- Response:

“The provision of emergency services and public assistance during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.”

– UNISDR 2009, p. 24

- Recovery

“The restoration, and improvement where appropriate, of facilities, livelihoods and living conditions of disaster-affected communities, including efforts to reduce disaster risk factors.”

– UNISDR 2009, p. 23

- Mitigation

“The lessening or limitation of the adverse impacts of hazards and related disasters.”

– UNISDR 2009, p. 19

- Preparedness

“The knowledge and capacities developed by governments, professional response and recovery organizations, communities and individuals to effectively anticipate, respond to, and recover from, the impacts of likely, imminent or current hazard events or conditions.”

– UNISDR 2009, p. 21

Preparedness can accordingly be thought of as part of the mitigation phase, although it's sometimes defined as a separate fourth management phase (e.g. Abdalla and Li 2010). The duration of the phases shown in Figure 1 can, according to the definitions above and those mentioned by Cutter (2003) be approximated to hours to weeks for the response phase and months to years for the recovery phase. The mitigation phase lasts indefinitely or until a new emergency event occurs.

As explained by Mansourian (2005); each emergency management phase should ideally be conducted in a way that facilitates success in the next phase, but in the case of rebuilding societies in the recovery phase this is often overlooked in favour of quickly restoring societies to their previous states.

Emergency events can occur in many different ways, as shown in Figure 1 by the three arrows representing the emergency event. They can strike with full intensity immediately and then slowly subside, like an earthquake which is followed by smaller after-shakes. They can slowly increase in intensity until they abruptly end, like a drought becoming increasingly severe until rain comes and quickly rejuvenates

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vegetation and fills rivers and lakes with water again. They can strengthen and weaken gradually, like a flooding disaster during which the water level slowly reaches its peak and then slowly retreats again. Events can also be singular surprise events, as the figure in Cutter (2003, p. 440) might indicate, which are over before any sort of response can be organized. Such events might be e.g. sudden landslides or singular earthquakes.

In line with the above definitions, the overlapping of the phases depicted in Figure 1 illustrates, first, that the response phase can begin while the emergency event is still ongoing. Second, restoration of facilities in the recovery phase can start (and might even be necessary) while rescue and relief is still being provided. Thirdly, it illustrates that mitigation concerns should be addressed already in the recovery phase so that the recovering society will be more resilient to future emergency events.

Regarding societies' resilience to catastrophes, it can be defined as:

“The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.”

Emergency Event

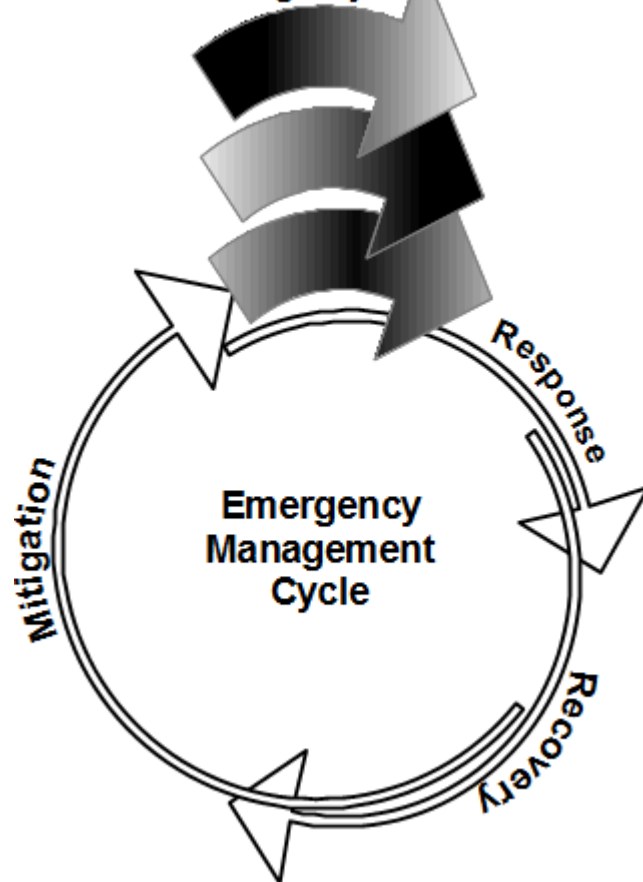


Figure 1: The emergency management cycle, showing the emergency management phases overlapping each other and that the actual event can occur differently. The mitigation phase continues until a new emergency event.

– UNISDR 2009, p. 24

Building resilience in a society includes many kinds of activities both aimed at preventing catastrophes from occurring or reducing their impact and at improving how the society can respond to and recover from them (Table 2).

A notable prevention strategy used in many countries is using land-use planning to restrict development in hazardous areas, albeit with different approaches to assessing risks and what actions to take (e.g. Cozzani et al. 2006; Glavovic et al. 2010). Other mitigation strategies include e.g. construction regulations, warning systems, protective

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structures such as flood barriers (Godschalk 2003; De la Cruz-Reyna and Tilling 2008; Glavovic et al. 2010) and evacuation plans (Saadatseresht et al. 2009). While many such strategies may be effective, there is also a need to ensure that plans and regulations are properly enforced. This is not always the case, especially in poorer countries, as discussed by Kenny (2012).

Table 2: Examples of strategies for mitigating catastrophe effects and for improving response and recovery after catastrophes. The division indicates whether they aim to prevent or reduce damage or to improve handling of damage after the event.

Mitigation	Response and Recovery
Land-use planning	Insurance against losses
Construction regulation	Education and Awareness
Warning system development	Response plans
Protective structures	Improvement of tools for emergency management
Plan and regulation enforcement	SDI development for improved decision making

With regard to coping with (responding to and recovering from) catastrophic events, building economic buffers to ensure the availability of resources, i.e. insurances, is a common strategy. Munich Re (2013a) estimate that approximately a quarter of the financial losses that occurred due to natural catastrophes 1980-2012 were insured. Of these insured losses, 81 % occurred in North America and Europe (Munich Re 2013a). Kenny (2012) also notes that the victims themselves still pay most of the cost associated with natural disasters and that this is even more true in developing countries than in developed countries. While potentially effective as an economic buffer system, insurance policies can hamper other risk reduction efforts during the recovery phase of emergency management. Glavovic et al. (2010), for example, discuss the effect in New Zealand, where private and government insurance policies against natural catastrophes do not cover improvements beyond the previous state of the property, which may be a factor in the neglect of mitigation needs during reconstruction mentioned above.

As another strategy for improving the response capabilities of communities, Shaw et al. (2009) discuss how disaster risk education can raise awareness about the nature of potential local catastrophes and what to do in such circumstances. In order to educate people on good conduct and their roles and responsibilities during emergency events, there is also a need for communities to plan ahead. Frazier et al. (2013) comment that there is no universally recognized way to measure plan quality, but identified e.g. expertise within organizations and high quality data and analysis as associated with better plans.

Emergency management plans for the response phase can include organizational hierarchies and partnerships, and roles and responsibilities for participants. It can include the setting up of one or more emergency operation centres (EOCs) in pre-defined locations, where emergency management leadership can gather to receive and analyse information, including spatial data, and coordinate rescue and relief efforts

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(Cutter 2003). Communication channels should be addressed, to enable cooperation also if current infrastructure breaks down (Comfort and Haase 2006). Also, there may be plans for providing emergency resources such as food, medicine, housing and search and rescue equipment.

There is also much research being done on developing better tools and technology for emergency management. These involve e.g. improved cooperation and decision making for EOCs through “group geo-collaboration” (Cai 2005; Zheng et al. 2008), feature extraction from satellite images (Mansourian et al. 2008), mobile GIS (e.g. Mobaraki et al. 2008; EL-Gamily et al. 2010) and community data sharing platforms (Clark et al. 2010). Additionally, it involves the development of regional, national or international spatial data infrastructures (SDIs) to facilitate the creation and use of spatial data (e.g. Vanderhaegen and Muro 2005; Mansourian et al. 2006; Bill 2008; Tu et al. 2010), which will be addressed in the following section.

Moving on, who are the stakeholders and participants in emergency management? Dynes (1970, referred through Scanlon 1999 and Mansourian 2005) categorized the participants into four groups based on what duties they perform in an emergency situation compared to during their normal operation. The first of these groups is *established organizations*, that are those organizations that under emergency situations continue their normal operations as usual, albeit under increased stress and perhaps with special emphasis on some tasks. These include for example police and fire-fighting organizations.

Expanding organizations are such organizations that have few or no emergency-related tasks in their normal activities and whose normal presence is small, in effect being dormant or absent until an emergency has occurred. These expanding organizations grow in size and take on tasks they don't normally do at that location. Disaster relief charities such as the Red Cross and Red Crescent Societies are examples of expanding organizations.

Extending organizations are existing organizations that, during emergencies, perform duties outside the scope of their usual purpose. Examples include Social Service Departments, Mental Health Services (Mansourian 2005) and construction companies using their equipment for debris removal (Scanlon 1999).

The fourth and last group is *emergent organizations*, which are informal groups of individuals that join forces more or less spontaneously to respond to relevant emergency needs. These groups may be prompted to act by recognizing needs that are neglected by organizations of the other types (Mansourian 2005) or may disagree with the current emergency management leadership.

Scanlon (1999) applied the categories proposed by Dynes (1970) to an ice storm disaster in Eastern Canada in 1998 and found that the framework was valid and that several of the hypothesized relationships were supported. The order of emergence of the organizational types, for example, was largely followed, with Established and Expanding organizations initiating their response before Extending and Emergent types of organizations. Scanlon (1999) noted that Emergent organizations could also consist of people from within organizations of the other three types and could be integrated into

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existing formal structures, in which case expected cooperation difficulties may not occur.

Finally, in addition to these functional organization categories, organizations can be governmental or non-governmental, military, public or private sector and can also act in a local, regional, national or even international jurisdiction (Mansourian 2005). Economically, organizations can be commercial or non-profit and can be funded by the sale of services and products, by charitable donations or by the government.

2.2.1. Spatial Data for Emergency Management

Spatial data are important in all phases of emergency management, but this section will deal primarily with the response and recovery phases. Some catastrophes that have exemplified the usefulness of spatial data in emergency management are the World Trade Center 9/11 terrorist attack in 2001 (Cutter 2003; Kevani 2003) and the Haiti earthquake in 2010 (Clark et al. 2010). Abdalla and Li (2010) justify using geospatial technologies for disaster management by acknowledging its ability to provide meaningful information, support decision-making and generate knowledge in a more time- and resource-efficient manner.

Spatial data can be used for disseminating effective public information through maps (Kevani 2003). They can improve information sharing and accelerate decision-making (Neuvel et al. 2012). They can provide logistics support by e.g. finding optimal paths for evacuation (Lee and Cheon 2007; Saadetseresht et al. 2009). Spatial data are also used for assessing the current state of emergencies by e.g. delineating catastrophe area boundaries (EL-Gamily et al. 2010), by finding damaged structures (Gokon and Koshimura 2012) and by tracking ongoing emergencies in general (Duda and Abrams 2012). Giardino et al. (2012) lists another few tasks where spatial data are of assistance:

- keeping track of search and rescue personnel for communication and coordination,
- recording and communicating the locations of important resources such as medical facilities and food and water supply points,
- and analysing ongoing threats in order to select safe locations for e.g. temporary housing or resources such as those mentioned above.

Despite its obvious usefulness during emergency response and recovery, there are also ample difficulties to overcome before spatial data and GIS can reach their full potential. For example, regarding field data collection, Kevani (2003) pointed out the difficulty in getting precise location data when using GPS (the Global Positioning System) with obstructive surroundings such as urban high-rise buildings and debris. In areas which has suffered extensive damage there is also a risk that the crucial but fragile communications infrastructure will be disrupted or go offline (Kevani 2003) with severe adverse effects on emergency management (Comfort and Haase 2006) and mobile GIS function.

Further, the use of spatial data requires a high level of skill from the users. Cutter

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(2003), from the experience gained during the 9/11 terrorist attack, even reasoned that what primarily determines the outcome when implementing GIS among first responders are their openness toward new technologies and the user-friendliness of the tools. Mansourian (2005) noted that spatial data are more demanding to collect, maintain, process, manage and use than other types of data, with regard to human expertise and equipment. Consequently, GIS and spatial data can be difficult and expensive to implement in an emergency management organization, organizations which are not always adequately funded (Mansourian 2005).

Another challenge with applying spatial data for emergency management identified by Mansourian (2005) is how to avoid the duplication of efforts that can occur when similar data are collected more than once because of a lack of cooperation and awareness between emergency organizations. A closely related issue is that acquisition of essential data from different sources can be difficult due to ownership and policy issues and a multitude of data incompatibilities (Kevani 2003; Mansourian 2005). This was also found in an Internet consultation held by the pan-European Spatial Data Infrastructure (SDI) initiative INSPIRE (Infrastructure for Spatial Information in Europe) in 2003. This consultation asked about obstacles to widespread use of spatial data to support environmental governance. It found that 97 % of the respondents agreed that some or all of the following five identified obstacles were among the primary challenges (INSPIRE 2003, p. 14):

1. *“Gaps in Spatial data: spatial data is often missing or incomplete,”*
2. *“Lacking documentation: description of available spatial data is often incomplete,”*
3. *“Spatial datasets not compatible: spatial datasets can often not be combined with other spatial datasets,”*
4. *“Incompatible geographic information systems: the systems to find, access and use spatial data often function in isolation only,”*
5. *“Barriers to sharing and re-use: cultural, institutional, financial and legal barriers prevent or delay the use of existing spatial data.”*

Although significant advances have been made during the last decade, these challenges have remained to varying degrees (see e.g. Bill 2008; Tu et al. 2010) and SDIs are still being further developed in new areas (e.g. Hamylton and Prosper 2012). The implementation of an SDI can be a useful strategy for effectively dealing with some of these challenges, specifically those relating to availability, accessibility, applicability or usability of spatial data (Mansourian 2005). Availability concerns the existence of data, so the 1st obstacle above concerns availability. Accessibility of data is whether or not regulations, policies and culture allow access to the user, applying to the 5th obstacle. Applicability considers whether the specifications, quality and source system of the data are compatible with user requirements (3rd and 4th obstacle). Finally, to be usable, data first have to be available, accessible and applicable. Usability though, can be further hampered by users' unawareness of the existence or characteristics (metadata; the 2nd obstacle) of data, and also their willingness or knowledge of how to use them.

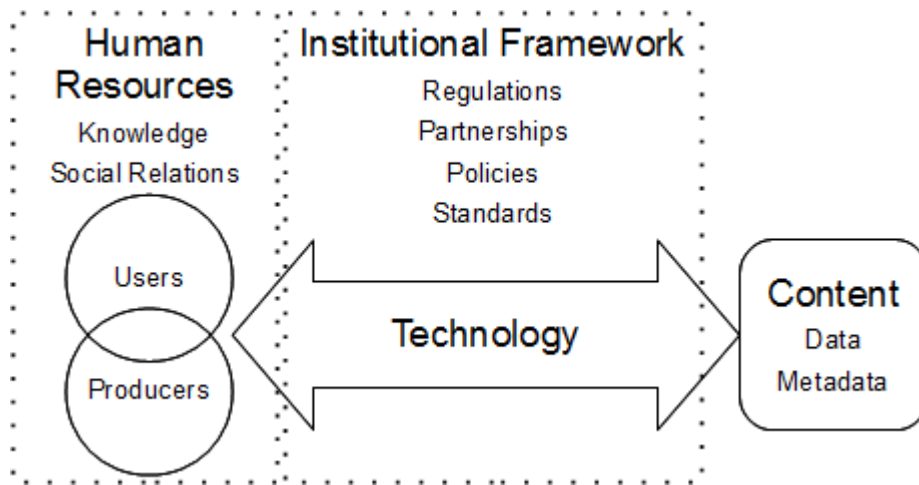


Figure 2: The components of a Spatial Data Infrastructure (SDI).

From a study of SDI definitions from multiple sources by Mansourian (2005), it can be concluded that there has been significant variability in the precise understanding of what comprises an SDI. On a basic level, an SDI is meant to assist in creating a suitable environment for cooperation and communication of spatial data within the geospatial community (Rajabifard et al. 2002). In the more specific definitions, many concepts are closely related and they overlap to a high degree, with most of the SDI definitions listed by Mansourian (2005) and that given by e.g. Bill (2008) in rough alignment with the model presented in Figure 2.

In Figure 2, human resources are the people component of an SDI with individuals and organizations as users or producers of spatial data, often both. They are at the same time both constrained and enabled by their social relations with other individuals or organizations and their knowledge about available data and technology and how to use them. Without relations with a producer of data, its available datasets will not be accessible, and without knowledge of how to apply the data to a specific problem it doesn't matter whether they are applicable or not because they are not usable. Human resources are as a whole affected by their cultural environment and society's and organizations' investment in education and staff.

Users and producers find, access and store content through technology, which can incorporate communication networks, server and client hardware and software, data collection and data storage facilities, data search and discovery services etc.

The nature of the technology component is dependent on an institutional framework that sets the rules and boundaries for access, production and use of the content. Regulations (e.g. national laws) and company and organization policies (including pricing) can determine what data is allowed to be shared and how it can be used. The contracts and agreements (partnerships) between organizations decide what will be, and together they determine the accessibility of spatial data. Standards define how to achieve it technically.

In the content component (Figure 2), metadata, i.e. information about data, are as

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important as the data themselves. As mentioned above, without metadata users may decide not to use otherwise available, accessible and applicable data. Either because they are not aware of the data at all, or because they cannot determine the nature and quality of the data.

Using the European INSPIRE initiative as an example, the availability of data can be improved by bringing stakeholders together and coordinating their data production efforts in order to fill identified gaps (Vanderhaegen and Muro 2005). An EU framework for sharing spatial data is a solution for overcoming economic, legal and procedural challenges with accessing and utilizing spatial data.

Accessibility is further tackled by implementing common integrated spatial information services, which, based on metadata, allow users to find and access relevant data. The metadata will also improve usability. In order to provide wide applicability all data from the European Union (EU) Member States must adhere to a common set of spatial data specifications.

As a last point regarding spatial data for emergency management, the roles of remote sensing techniques and mobile field data collection systems will be briefly discussed. The modern very high resolution (VHR) optical and synthetic aperture radar (SAR) aerial and satellite sensing systems are becoming more and more useful for emergency management. With the improving capacity to automatically extract useful information about human settlements, such as buildings, roads and open spaces (Mansourian et al. 2008; Pagot and Pesaresi 2008; Al-Khudhairy 2010; Liu et al. 2012) the use of satellite and aerial remote sensing for emergency management is becoming increasingly common (e.g. Duda and Abrams 2012).

Liang et al. (2005) describe another type of remote sensing where hosts of miniaturized sensors, capable of sensing and recording a wide range of variables form in situ or remote monitoring networks, i.e. sensor webs. This is another group of technologies that are now considered for emergency management (Kamel Boulos et al. 2011).

However, as previously mentioned, there are types of data that cannot be captured with remote sensing techniques. Considering satellite and aerial imagery, such data include most types of data from indoor environments and otherwise hidden areas (e.g. areas obscured by clouds) and types of data that are either too small to capture remotely or do not have easily distinguished visible (i.e. radiative) components. The latter could include e.g. human moods, opinions or medical diagnoses. In these circumstances sensor-webs may still be very useful tools with a growing number of sensor types and a virtually limitless potential. Especially considering current developments in computerized visual and acoustic recognition software (e.g. smartphones listening for the sound of a car crash; White et al. 2011).

In spite of their growing potential, there is a lack of flexibility inherent in remote sensing techniques that stems from the fact that the data they collect are specified in advance, based on the anticipated needs of the emergency management community before the nature of the event has become clear. There may be unanticipated consequences, bringing unanticipated needs for spatial data that current remote sensing systems are not developed for. In such cases, emergency management organizations

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may still have to rely on field data collection by employees and/or volunteers.

2.3. Field Data Collection & Mobile GIS

As outlined in the previous section, there are situations which require people to collect data on the ground as opposed to using remote sensing techniques. The importance of mobile GIS in emergency management has long been recognized (Kevani 2003), and Mobaraki et al. (2006) identify two primary uses, namely field data collection for updating EOC databases and for providing emergency workers with in-the-field access to EOC databases, to enable them to view and analyse current data about the emergency situation. By providing examples of related research and the recent history of the development of field data collection and mobile GIS, this section should aid the reader in comparing the current project with and distinguishing it from previous research.

Recent developments in the software and hardware of mobile devices have made real-time field data collection a reality and much research has been done on using such mobile devices for that purpose. The following section provides a brief overview of the recent development history of mobile GIS applications, by giving examples of such research projects.

Sauvagnargues-Lesage et al. (2001) used GPS units mounted on cars to collect data for fire-fighting in France's Mediterranean area. These data, comprised of forest tracks, fire hydrants and other features of importance to fire-fighting, was used mainly to produce analogue maps. GPS technology was an important improvement that allowed more efficient data collection, which in turn enabled more frequent updates of their database. While up-to-date maps can give good information about the pre-deployment situation, the system can not fully be considered a mobile GIS as it did not supply field personnel with the in-the-field database access mentioned above.

Another project that similarly used dedicated GPS devices mainly for collecting data, about building condition and attributes, is that described by Montoya (2003). A further development explored in this project was the use of remote sensing data and GIS for planning the field data collection efforts and the synchronization of digital video capture devices (video cameras) with GPS data so as to acquire georeferenced video material. This proved a useful method for quickly screening particularly important areas but still required post-processing to classify the data and return them as useful information to the field personnel.

As more advanced mobile devices such as Personal Digital Assistants (PDAs) and eventually smartphones started to have sufficient memory capacity and computing power they were increasingly used for mobile GIS. Lattanzi and Bogliolo (2002) and Casademont et al. (2004) described early projects that used PDAs to display maps downloaded from a remote server. The latter project also implemented a micropayment system and encryption to protect map information from unauthorized usage.

More recently, mobile GIS research has included sending collected data to a remote server as well as updating information stored on that server (Zhang et al. 2009). An interesting approach in situations where access to wireless networks is limited or

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impossible, for example because the infrastructure hardware has been destroyed in a disaster, is that by EL-Gamily et al. (2010). Their project utilized a laptop computer as a mobile server that was brought to the field and communicated with client devices through local Wi-Fi.

In the last few years, with the improvement in hardware and number of features in modern smartphones, these are being increasingly favoured as mobile GIS devices. The various sensor types, in particular, are being explored to collect new kinds of data and, as proposed by Hwang and Yu (2012), even to improve the overall accuracy the GPS measurements.

Two projects which developed smartphone applications that relied on utilizing the smartphone GPS receiver, but not mainly for mobile GIS, are those by Whipple et al. (2009) and White et al. (2011). The application by Whipple et al. (2009) integrated the location awareness with a web search service that provided the location of nearby schools, so that it could notify car drivers if they were driving too fast in a school zone. The project by White et al. (2011) integrated the use GPS with other smartphone sensors, namely the accelerometer and microphone. While the device is worn by a person in a car, rapid changes in the device's velocity and loud noises could indicate that the car crashed. From analysing the accelerometer and microphone sensor data, and upon detecting an accident, the application subsequently sent the device's current location and accident information to the emergency services. Finally, other application users could locate nearby accidents on a map in their device to e.g. avoid the accident location or to supply additional information about the accident to the emergency services.

A field data collection application for smartphones that was recently developed is GeoTools by Weng et al. (2012). It similarly used the smartphone's GPS receiver, accelerometer and microphone, but also used the camera. It was tailored specifically for geological field studies and thus used the accelerometer to estimate the orientation of the device, so that it could be used as both a compass and an inclinometer in addition to saving notes, recording video and audio and attaching the GPS coordinate and current time to each record.

There are now also commercially available mobile GIS that includes field data collection, such as the ArcPad by ESRI (2013a) or the Mobile MapWorks by Intergraph (2013a), to mention a couple of the larger competitors. Today both of these products offer visualization of spatial data stored on remote servers, field data collection, editing of server data as well as analysis tools.

To summarize, mobile GIS has come a long way since the turn of the century. It has advanced from mostly utilizing dedicated GPS devices to acquire location data and manually writing down the data, to fetching and uploading GPS coordinates and a multitude of other sensor data to a server remotely, as well as visualising, editing and analysing the server data – all in a single device.

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2.3.1. Volunteered Geographic Information & Crowd-sourced Data

The evolution of the Internet towards what is called Web 2.0 is making an ever greater portion of the content on the web user-generated (Goodchild 2007). The general public is getting increasingly used to sharing information publicly on blogs, image hosting services, community websites and other social media. This does not exclude sharing information with a spatial component. Recent efforts have, quite successfully, aimed at tapping into this resource (Clark et al. 2010; Meier 2012), showing that the emerging field of Volunteered Geographic Information (VGI; Goodchild 2007) has a great potential for quickly generating large amounts of data.

Data can be collected both passively with the users' implied consent, as in the project by White et al. (2011) described above, or by requiring the participants, i.e. the crowd, with varying experience and backgrounds to actively interpret and record features for crowd-sourced data collection.

An example of the latter is the EpiCollect project by Aanensen et al. (2009), which was created to enable smartphones to collect and send epidemiology data (as text, location, photos etc.) to a central database and visualize them in the smartphone display. Its first component was a smartphone application that was installed on users' devices. The second component of the system was a web application on a website that showed collected data and allowed analysis as well as a data entry form. Importantly, both the smartphone application and the web application were generic with respect to the data model. That made the system useful for field data collection in many different projects, each with their own requirements regarding data types and users' experience.

Another VGI system is the OpenStreetMap (OSM 2013), which has been around since 2004 and that has engaged hundreds of thousands of volunteers for producing a free vector-based world map (Haklay et al. 2010). The contributors map roads and other features using GPS enabled devices or by digitizing from aerial, satellite or other map imagery. Being free and available to all, and being produced by a community of widely distributed volunteers means that the information is often the least expensive alternative and may in some areas be the only available choice (Goodchild 2007).

With regards to using VGI for emergency response, already at the time when Goodchild (2007) introduced the concept of VGI, he noted that it had an interesting, but so far not used, potential for quickly generating crucial data for emergency management. As predicted, this has since changed rapidly. The OpenStreetMap system described above is one of the VGI tools that has been put to use during crises, as described by Shanley et al. (2013), for example by enlisting 3000 volunteers for analysing 24 000 aerial images of the emergency situation after the 2012 hurricane Sandy.

The Ushahidi platform is a second example of a VGI system used for emergency data collection (Ushahidi 2013). The word ushahidi, in Swahili, means “testimony” and the platform was initially developed in 2008 as a means for people in Kenya to report violence after the 2008 election using SMS (Short Message Service) messages from mobile phones and in a web form. Reports were published on a web map so that it could be viewed and analysed by everyone. It has since been further expanded to e.g. also allow Twitter posts and e-mail for reporting all kinds of information valuable during

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crises. The platform was used after the earthquakes in Haiti and Chile, the floods in Pakistan and the Russian wildfires in 2010, the 2011 earthquake and tsunami in Japan, Hurricane Sandy in 2012 and many other disasters (Baker 2012; Meier 2012; Ushahidi 2013).

As a final example, during the Haiti earthquake of 2010, a joint effort by the U.S. Military and the GIS company Thermopylae resulted in the development of User-Defined Operational Picture (UDOP; Clark et al. 2010). UDOP formed a common platform for gathering, creating and sharing spatial data from multiple sources and making them available to the whole emergency relief community and beyond. Because data could be imported into UDOP from any geospatial source and viewed by anyone, it could function as a hub of information where a host of data sets from different sources could be displayed together to make complex analyses. A versatile data export tool added a data “marketplace” function so that contributors could not only use UDOP itself but also download data for further analysis. Field data collection was considered “one of the most effective methods for building knowledge within the system” (Clark et al. 2010, p. 255) and to that end the mobile application “Disaster Relief” was developed and distributed. The application empowered any smartphone user to send data such as text or photographs with coordinates to the UDOP platform.

With the new wealth of spatial data being generated by ad hoc communities and isolated individuals comes the question of whether or not it can produce trustworthy and useful information. Goodchild and Glennon (2010) suggest that the example of the online encyclopedia Wikipedia may also be relevant for VGI in the sense that as the number of contributors to a project or to specific information increase, so does its quality or accuracy. Essentially because there are more people checking for errors. Haklay et al. (2010) present some early research on this topic, which indicates that Linus' law, as the concept is termed in open-source projects, may apply to VGI to some extent. The findings, which relate to the accuracy of roads in the OpenStreetMap, show that while the relationship between the number of contributors and accuracy is not linear and is of varying significance, the overall accuracy of the contributed data is high.

When gathering unstructured crowd-sourced data such as SMS messages, the challenge of making out useful information can be tackled by e.g. applying pre-processing to simplify the text and by categorizing, clustering and visualizing quantifiable variables like the need for drinking water during an emergency (Barbier et al. 2012). However, as summarized by Barbier et al. (2012), there are situations when crowd-sourcing or VGI may not be appropriate. These include when the required information is not generally known by the public (or not known well enough to give proper responses) or when the problem at hand is not interesting enough to engage a sufficient number of volunteers.

As a final remark regarding spatial data quality for emergency management, in some emergency situations, data availability is more important than data quality. Many would prefer to e.g. evacuate unnecessarily due to faulty information than to be caught in a disaster because no information was available (Goodchild and Glennon 2010). Thus, using VGI and crowd-sourcing for emergency management shows clear potential for improving the response capability and efficiency, but presents new sets of challenges.

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2.4. Technology

The above sections illustrate the wide range of strategies and technologies that can be used for collecting spatial information while allowing the free movement of its user. To be able to explain and justify this project's specific implementation of the proposed system, the primary alternatives for components and characteristics will be presented in the following sections.

First, smartphones, which are becoming increasingly popular for mobile GIS, all require an operating system (OS) to handle communication between its hardware and any installed applications as well as providing out-of-the-box access to many functionalities we have come to expect of modern smartphone devices. What system is included depends on the device manufacturer. Second, a spatial server of some sort is required to relay information to field personnel, i.e. allowing them to view maps and spatial data remotely. Third, system interoperability can be vastly improved by the development and use of standards for their communication.

Finally, given system compatibility and the existence of a suitable mobile application for the specific purpose, it is still not certain that the user is allowed – or can afford – to use the application. Smartphone applications, as other types of software, are subject to copyright laws and the author determines through license terms what a user is allowed to do with it and whether there is a cost to acquire it. However, a growing body of software use some form of open-source license which, among other rights, let the users acquire the source code for free, modify it for any purpose and redistribute it to other people.

Thus, the following contains brief descriptions of major mobile platforms (OSs), spatial server systems, standards for spatial data communication and open-source licenses.

2.4.1. Mobile Platforms

The four most common smartphone operating systems, by market share in the third quarter of 2013 (IDC 2013) are:

- Android by Google, with a distinct dominance at 81 %,
- iOS, on Apple's iPhone, at 12.9 %,
- Windows Phone by Microsoft at 3.6 %
- and BlackBerry at 1.7 %.

There are many significant differences between these platforms. Some are visible to the users such as availability of specific features or design of the user interface (UI), and some are invisible to the users but affect the developers of mobile applications.

When comparing the two most common platforms, from an education perspective, Goadrich and Rogers (2011) found both to be valid choices for creating courses around, each with their own advantages and disadvantages. An advantage of Android compared to iOS was that application development was possible on most computers, while iOS development required the use of Apple's own computers. They also noted that the

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programming language of Android could be expected to be more familiar to students than that which is used for iOS. Goadrich and Rogers (2010) further highlighted the tools used for developing applications for iOS (the iOS Software Development Kit) as well designed, tested and documented, in part explained by its higher age compared to Android.

In a somewhat older comparison of mobile platforms Anvaari and Jansen (2010) analysed, from an openness perspective, the platforms Android, iOS, BlackBerry, Windows Mobile (the predecessor to Windows Phone) and the now discontinued Symbian (Thomas 2013). They compared the possibility, due to the platform architecture, and the right, determined by licenses, to use, extend and modify software components in different layers of the platforms. Through interviews with developers they found that perceived openness relies on more factors, such as the platform documentation, examples for developers and the community around the platform. Nevertheless they could show that, according to their model of openness, Android and Symbian were clearly more open than Windows Mobile and BlackBerry, with iOS on the far end of the spectrum as the least open platform.

Among previously mentioned research projects, Aanensen et al. (2009), Whipple et al. (2009), White et al. (2011), Dezani et al (2012) and Weng et al. (2012) used Android. For the UDOP project in Haiti, iOS was initially used, but an Android version of the application was also made, as well as versions for “other popular mobile platforms” (Clark et al. 2010, p. 256). Zhang et al. (2009), EL-Gamily et al. (2010) and Xu et al. (2010) used Windows Mobile on PDA devices.

An interesting approach that allows applications to be installed on any mobile platform is that by Chen et al. (2012). They built a mobile data collection application using Adobe AIR (Adobe 2013), meaning that their application can be used on any device that supports AIR including Android, iOS and BlackBerry.

2.4.2. Geospatial Servers

Geospatial servers are software systems that receive requests for, and return, spatial data in different forms to users or clients. They are often comprised of a spatially enabled database management system (DBMS) and a spatial data publishing software (Figure 3). The DBMS stores and handles the data sent to it in a spatial database. The publishing software can come in many forms but is often a web map server which, based on user requests, returns maps and data, inserts data or otherwise manipulates data in the database. The publishing software may use an included, or separate, web server for managing communication over the Internet. It may also publish data from remote data sources such as spatial databases on remote servers or other storage types. Access to remote data sources may be over the Internet or through local networks.

There are many alternatives for both of the main components of the server system, both from vendor companies who produce and sell proprietary software and from open-source communities where the software is usually free of charge and the source code is available to everyone. Detailed descriptions and comparisons of each software alternative is outside of the scope of this project.

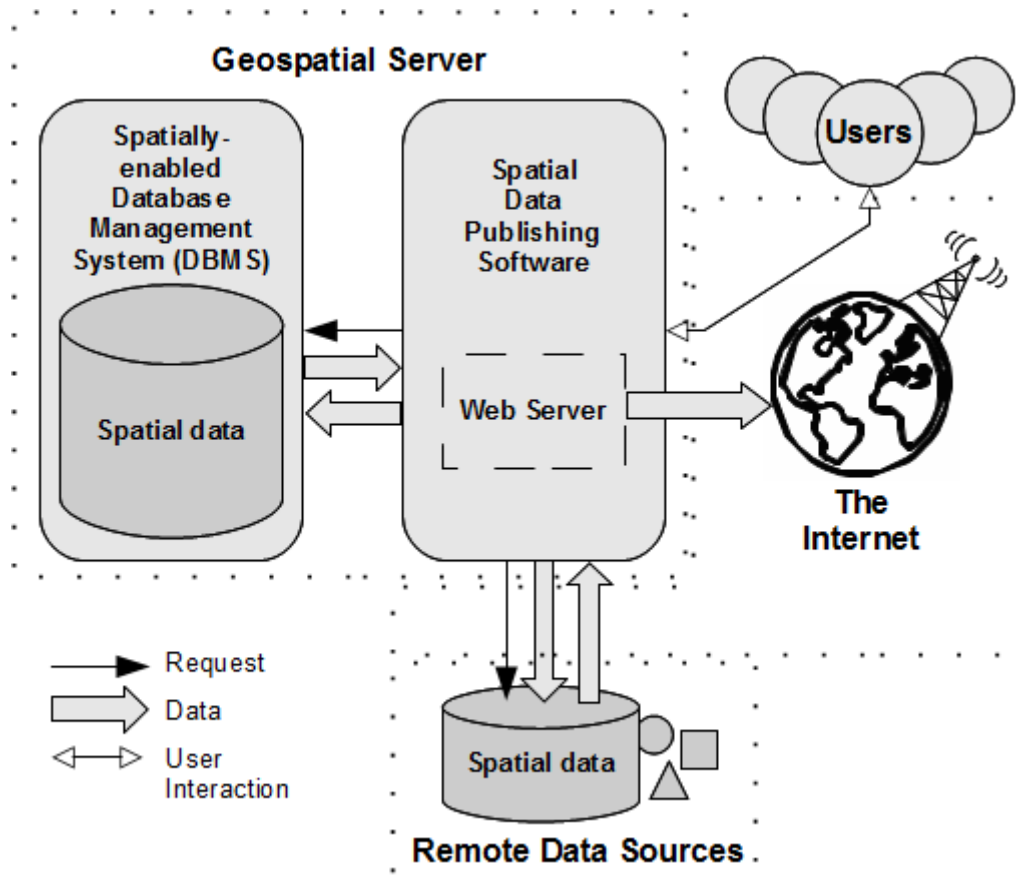


Figure 3: The composition of a geospatial server system.

Some of the most prominent examples of proprietary spatial DBMSs include:

- ESRI's ArcSDE (Spatial Database Engine; ESRI 2013b) that adds spatial functionality on top of other database systems and is in recent versions included in their ArcGIS Server software package,
- Oracle Spatial (Oracle 2013a), which supports spatial data types natively and has a scaled-down version that is included with the less expensive Standard Edition and a full version that requires the more expensive Enterprise Edition,
- and Microsoft's SQL Server (Microsoft 2013), that has full spatial functionality in all editions (less expensive editions have other, non-spatial, limitations).

In the open-source realm, the most popular spatial DBMS is PostGIS, with MySQL Spatial and the SpatialLite project as main competitors (Steiniger and Hunter 2013).

- PostGIS (2013) is a spatial extension for the open-source object relational database PostgreSQL (2013),
- SpatialLite (Furieri 2013) is an extension library for the lightweight relational database SQLite which, due to it being used on multiple major smartphone platforms and web browsers, is likely the most widely deployed database in the world (SQLite 2013),

- MySQL (Oracle 2013b), also owned by Oracle, which may be the second most deployed open-source database engine and the most popular of the full-fledged server DBMSs.

While there are many technical differences between software alternatives, they may often be interchangeable for the common use cases since they are developed to be used in mostly similar ways. For example, the open-source web map server software GeoServer (2013) is, through extensions, capable of publishing spatial data stored in all of the spatial databases types above and a few more, excluding SpatiaLite.

GeoServer together with MapServer (2013) are the two most well-known open-source web map servers (Steiniger and Hunter 2013). Two examples of commercial competitors are ArcGIS Server by ESRI and ERDAS Apollo by Intergraph (2013b), both of which also offer cloud-based map services, meaning that the maps can be published on shared servers managed by the company instead of on the users' own systems.

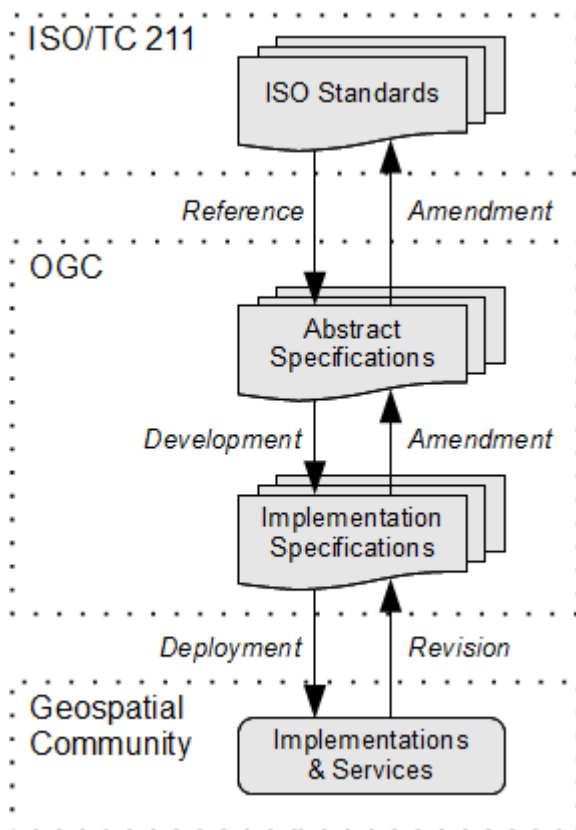


Figure 4: A global spatial data standards infrastructure model with four levels of abstraction, from the practical implementations in the geospatial community to the most abstract level of the ISO standards. Adapted from Yeung and Hall (2007). Note that the model by Yeung and Hall also include national and regional standards organizations which are left out in this figure.

2.4.3. Standards

By using common standards for storing spatial data and for communication between the geospatial server and the clients (i.e. the mobile devices), a level of interoperability can be achieved that allows flexibility in the composition of the client-server system. This interoperability has long been recognized as an issue with spatial data and GIS for emergency management (e.g. Cutter 2003; Mansourian 2005; Abdalla and Li 2010).

Today there are a number of organizations that develop standards for spatial data and communications. Most notable are the International Organization for Standardization's Technical Committee 211 (ISO/TC 211) and the Open Geospatial Consortium (OGC 2013). They are cooperating officially since 1998, adopting and referencing each other's standards (ISO/TC 211 2009).

The ISO/TC 211 deal with spatial data

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and GIS in general, including what is likely the most comprehensive set of spatial data standards to date (Yeung and Hall 2007). ISO defines standards on a more abstract level, especially compared with the OGC's implementation specifications. Thus, for the purpose of this report, details about the ISO standards are considered outside the scope, but their content can be summarized as the overall objectives of the ISO/TC 211 (2009, p. 7), which are to:

- *“increase the understanding and usage of geographic information;”*
- *“increase the availability, access, integration, and sharing of geographic information;”*
- *“promote the efficient, effective, and economic use of digital geographic information and associated hardware and software systems;”*
- and to *“contribute to a unified approach to addressing global ecological and humanitarian problems.”*

OGC defines two types of standards, namely: (1) abstract specifications as conceptual frameworks for interfaces and services, and (2) implementation specifications to guide personnel charged with developing such systems in practice (Yeung and Hall 2007). From the cooperative relationship between ISO and the OGC and the different levels of abstraction in the sets of standards, Yeung and Hall (2007) defined a model of the global spatial data standards infrastructure (Figure 4). In their model the implementations and services that are developed by the geospatial community are deployed based on the OGC's implementation specifications. The implementation specifications are developed from the abstract specifications and are revised based on feedback from the community. Through changes required in the implementation specifications, amendments are made to the abstract specifications. Changes in these, in turn, prompt amendments to the ISO standards which are referenced by the abstract specifications. Yeung and Hall (2007) conclude that while their model is a good starting point, there is still a lot of work ahead to achieve harmonization and interoperability.

The OGC standards that are of interest for the current project are presented in Table 3. They can be separated into those concerning spatial data and those concerning web mapping. They are all related to each other, with

- SFS defining the basic model of spatial features,
- GML specifying how the features and their attributes should be encoded for exchanging data,
- WMS determining how client-server interfaces should work to present spatial features as map images,
- WFS determining how client-server interfaces should work for accessing spatial data, e.g. through queries, or insertions, modifications or deletions of data,
- and finally with SLD specifying what styles and symbology to use for map images and spatial data visualization.

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Table 3: The standards by the Open Geospatial Consortium (OGC 2013) that are relevant for this project, separated into spatial data standards and web mapping standards.

Spatial Data Standards

SFS Simple Features Specification. Defines a system of spatial features, their properties and relations and how they should be represented and handled in different formats.

GML Geography Markup Language. A standard for describing, or encoding, spatial features in a structured way using XML. Features represented by points, lines or polygons together with their non-spatial attributes can be read, stored and exchanged as GML encoded documents. GML uses two types of documents: schema documents that describe the data model used and instance documents with actual data encoded based on their GML schema.

Web Mapping Standards

WMS Web Map Service. An interface standard for communication of map images based on data from e.g. geospatial databases using HTTP requests. Can also refer to a specific implementation of the WMS standard.

WFS Web Feature Service. An interface standard for accessing and altering geographic data, e.g. in geospatial databases. Can also refer to a specific implementation of the WFS standard. Implementations of WFS communicate spatial data encoded in GML.

SLD Styled Layer Descriptor. A standard that extends WMS and WFS functionality to allow clients and users to specify the styling and symbology of requested layers. Simply put, this is done using standardized XML encoded documents, similar to GML documents but for styling and symbology.

Regarding the use of these standards for emergency management, Charvat et al. (2008) discuss how multiple organizations with different demands on map layout and symbology can, in emergency situations, be required to collaborate by accessing and collecting data for the same data sources. In this scenario, specific map set-ups that were created by one organization for their specific purpose may not be clear and understandable for another organization. Here, the SLD standard together with other specifications can be an important solution that enables multiple visualizations of the same underlying data sets, geared to each organization's specific needs.

Lastly, a number of relevant standards are defined by the World Wide Web Consortium (W3C 2013), including the XML (Extensible Markup Language), a standard for writing documents in a way that can be read by both humans and computers, and the SVG (Scalable Vector Graphics), that defines a vector based image format sometimes used for displaying spatial data.

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2.4.4. Licensing of Free and Open-Source Software

Using open-source licensing for software is a way to help enable collaboration between developers, which can lead to better and more reliable software (Stallman 2009; Steiniger and Hunter 2013). This likely applies to mobile applications as well. These licenses regulate what users are allowed to do with computer programs and software, which are by default covered by international copyright laws. This means that, unless otherwise stated, users are not allowed to copy, modify or redistribute the source code of any computer program, which is what open-source licenses are designed to rectify.

When selecting a license for new software projects, a common license may be easier to use than an uncommon one, or a license written specifically for that project. Common licenses may have better documentation, more agreed-upon interpretations and may be tried in courts to better define their meaning.

The Open Source Initiative (OSI), through its Open Source Definition, is a community recognized authority on open-source licenses (OSI 2013). The OSI's definition is comprised of ten requirements that licenses must fulfil in order to be considered open-source. Simply put, the licenses must allow the covered software and its source code to be:

- accessible,
- usable,
- modifiable,
- and be possible to redistribute.

Within the open-source community, there are proponents of stronger forms of open-source licenses which, in addition to the user rights above, also require a reciprocity. That is, these so called “copyleft” licenses require that modified or derived works are released under the same licenses as the original so that these rights are paid forward. As supporters of copyleft software licensing, the free software movement advocates making a distinction between open-source software and free software (Stallman 2009). By talking about free software (free as in “free speech”, not “free beer”) instead of just open-source, it is hoped that users will better recognize the essential freedoms and the ethical aspect of free and open-source software. “FOSS4G” (Free and Open Source Software for GIS/Geospatial) is an organization and a name used specifically in the geospatial community (Steiniger and Hunter 2013).

Using an open-source license scanning tool, recent results showed that the five open-source licenses listed in Table 4 were the most commonly used in open-source projects (Black Duck Software 2013). The analysis tool scans the source code and any license files on code repositories for forges (collaboration platforms), foundations, organizations etc., so there may be types of license notifications that are missed. Nevertheless, with the clear domination of the licenses in Table 4, it seems likely that they are indeed the most common open-source licenses.

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Table 4: Top licenses used in open-source projects. Adapted from an analysis of projects in forges (collaboration platforms), foundations and organizations by Black Duck Software (2013).

License	Portion of projects
GNU General Public License (GPL) 2.0 + 3.0	45 %
Apache License 2.0	13 %
MIT License	11 %
GNU Lesser General Public License (LGPL) 2.1 + 3.0	9 %
BSD License 2.0	7 %

The GNU General Public License (GPL) is a copyleft license as described above. Thus, it bestows on any user the right to access, use, modify and redistribute the software and its source-code, but also require that any such modifications or derived works are released under the GPL (OSI 2013). Importantly, if the software is distributed, in its original or modified form, or as part of a larger program, then the entire program needs to be licensed under GPL.

The latter point is the major difference between the GPL and the LGPL (GNU Lesser General Public License). The LGPL does allow the software to be used without the entire program being forced to use the same license, only the parts originally under LGPL are required to stay such. So, contrary to GPL, any user can include LGPL parts in a proprietary program as long as the specific covered parts are offered under LGPL, with the basic open-source rights presented above. Because of GPL being less permissive toward the users, it is considered “strong” copyleft while LGPL is considered “weak” (Sen et al. 2008). Licenses that do not require modified or derived works to in any way keep the original license are known as non-copyleft.

The second most common open-source license is the Apache License 2.0 (Table 4), which is considered non-copyleft (Sen et al. 2008). Simply put, it gives the basic open-source rights with only a few restrictions for the protection of the original author (OSI 2013). For example, any license notices need to be kept intact and any modifications clearly stated. This way, modifications and derived works are not mistaken for the original code and the original author can under no circumstances be held liable. Also, interesting for collaborative projects, is that any improvements sent back to the original author automatically fall under the Apache License 2.0, so that they can easily be incorporated into the project.

The MIT License and the BSD License 2.0, which are similar and also non-copyleft (Sen et al. 2008), are even more permissive toward the users than the Apache License. Basically they allow any use of the software as long as the copyright notices (including author disclaimers and no-warranty clauses) are kept (OSI 2013).

The following are three examples of previously mentioned open-source projects:

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- Aanensen et al. (2009) who used the Apache License 2.0 for their EpiCollect Android application,
- the Ushahidi (2013) platform, which uses the LGPL for all its software,
- and the PostGIS (2013) spatial database extension for PostgreSQL (2013), which is released under the GPL (2.0).

3. System Design

In this section, a system architecture for emergency field data collection is designed based on identified needs of emergency management organizations and emergency field personnel. The client-server relationship and the system components with their desired characteristics are presented.

3.1. Requirements

Based on the studied research about and lessons from GIS in emergency management, implementing the proposed architecture should yield a system that:

- 1) is user-friendly,
- 2) produces accurate data,
- 3) can stay operational in areas and situations where network connectivity is lost,
- 4) has the basic functionality to:
 - a) show maps (and satellite imagery),
 - b) fetch the user's location using GPS,
 - c) create point, line and polygon geometry,
 - d) input feature attributes,
 - e) and upload data to a geospatial server,
- 5) can be extended to include GIS processing such as:
 - finding the length of a line or the area of a polygon,
 - shortest-path evaluations to specific locations (navigation) or to objects of specific types (search)
 - etc.,
- 6) and works on a wide range of devices.

The user-friendliness, or usability, of a product or system is defined in the ISO standard 9241:11 as the degree to which a group of users are able to achieve specific goals using it, within a specific context (ISO 2013). It is also broken down into *effectiveness*, *efficiency* and *satisfaction*, which are defined as how well the goals are achieved, how much resources are required and the users' comfort and attitude towards the system,

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respectively. A fourth aspect of usability that is often added is *learnability*, relating to the time and effort required to learn how to use the system (Jeng 2005). Henceforth, when user-friendliness is used it includes all four of these aspects.

While it's an advantage for systems to also be easy for administrators to install and manage, with technically experienced staff this could be considered a secondary objective. The end-users, in this case the emergency field personnel and volunteer groups, need to quickly understand the user interface and how to pursue the assigned objectives using the system, in order to achieve a high participation rate and small need for technical support. Well crafted written instructions and tutorials can be effective in compensating for the system complexity. The system used by Clark et al. (2010) could illustrate this, as there were brief training videos made available which, in their case, were found to reduce the technical support requests to the EOC by 70 %.

Data accuracy relates both to the spatial accuracy of collected data and the thematic accuracy, that is, the accuracy of feature classification, naming and attributes. The former is determined by the hardware of the data collection device, the number of and angles to available GPS satellites and whether signals are being blocked by the surroundings, e.g. by trees or buildings. Research have found that recent smartphones have an average accuracy of 15-20 m outdoors, but that it can be as good as a few metres (e.g. Zandbergen 2009, Retscher and Hecht 2012). While the thematic accuracy depends largely on the experience and meticulousness of the field personnel and volunteers, system design can have a large impact on the types and amount of errors that are made. For example, by using lists of acceptable values (enumerations) instead of free text or number value input, or by restricting input to specific formats, such as digit-only input for integers, many common errors can be avoided.

A further important aspect related to data accuracy is that of semantic heterogeneity (Pundt 2002, 2005; Charvat et al. 2008). Organizations with different objectives may collect similar data for different purposes but with different naming conventions or, conversely, they may use similar names for disparate concepts. Charvat et al. (2008) recommend the development of a common thesauri for unifying the use and understanding of common concepts. The definitions developed by the UNISDR (2009) could be adopted to provide such a common vocabulary and could perhaps, if expanded upon to provide more emergency organization-specific terminology, be used effectively in data models as well.

Offline capabilities of field data collection systems and mobile GIS are an important feature for emergency management (Comfort and Haase 2006; Clark et al. 2010). A system designed to work during and after major disasters need to be resilient widespread to infrastructure damage and also need to be applicable in undeveloped regions where wireless network connectivity may not be available.

Regarding the basic functionality, they are quite self-explanatory. To “show maps” includes operations that modern digital map users have come to expect such as being able to pan, zoom and select layers for display in the map. It should also include satellite imagery to facilitate navigation and feature creation in otherwise feature-poor areas (such as wilderness, where traditional maps are lacking). While a data collection system

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that only collects point features may be useful, to be able to record many of the required features for emergency management (see e.g. Mansourian 2005; Shanley et al. 2013), line and polygon support is also required.

Considering that more advanced GIS processing is becoming possible to use on mobile devices (Kambara et al. 2011), an extensible system can realise the potential of mobile GIS to a greater extent.

For quickly generating required data for emergency management, make use of crowd-sourcing and VGI, the system needs to reach a lot of people. Given all other requirements, if the system is not compatible with a sufficient number of common device types it will not be possible to utilize the hardware already present. Procuring compatible devices for field personnel and volunteers would likely not be feasible because of time, costs and the users' unfamiliarity with the new devices.

Because of the general nature of the above requirements, while also advantageous for emergency management, they would benefit field data collection and provide mobile GIS capabilities for any purpose. The following characteristics, on the other hand, could be considered to be especially important for emergency management, so the implemented systems should also:

- A) be collaborative (as in enabling inter-organization collaboration),
- B) use open-source licenses,
- C) comply with relevant standards,
- D) and provide data security.

Giving emergency management, field personnel as well as EOC staff, access to data from multiple organizations through the same system could facilitate the sharing of information and coordination of data collection. This way, all participants benefit from a wider spectrum of data, the duplication of efforts can be minimized and new information may be revealed through data synergies.

Through the use of open-source licenses for the system it can be accessible to everyone, both in terms of the legal and organization policy situation and its affordability. Each emergency response and recovery effort differ from the next with respect to its participants and the data and tools that are required. Here, open-source licenses greatly simplify the process of modifying, updating or otherwise changing the system to suit the situation at hand. Additionally, it allows for a collaborative development process between a changing composition of developer organizations and individuals.

By complying with the relevant industry standards, such as those by the OGC described in a previous section, the system can achieve a higher level of interoperability, thus enabling a greater number of organizations with varying tools and spatial data formats to share and use all available data.

Finally, data and information security, through e.g. user authentication and privilege management such as that used by Casademont et al. (2004) is also sometimes considered a requirement (e.g. Charvat et al. 2008). It may be considered a low priority

in emergencies due to the relative importance of saving lives through the dissemination of correct and relevant information during crises. Nevertheless, there could exist reasons for certain data to not be publicly shared. It could be an expensive product produced by a privately owned company demanding compensation, a “business secret” not allowed to be shared with the owner's competition, there may be public safety, privacy or personal integrity concerns with sharing the data and there may be legal issues etc.

3.2. Architecture

Figure 5 shows the result of studying the field of emergency management and mobile GIS and combining the requirements in the previous section to a single integrated emergency field data collection architecture.

A user with a smartphone as mobile GIS device receives location data from GPS satellites through the GPS receiver in the smartphone. Spatial features are created with the user interface of the client mobile application. These are then sent over the Internet

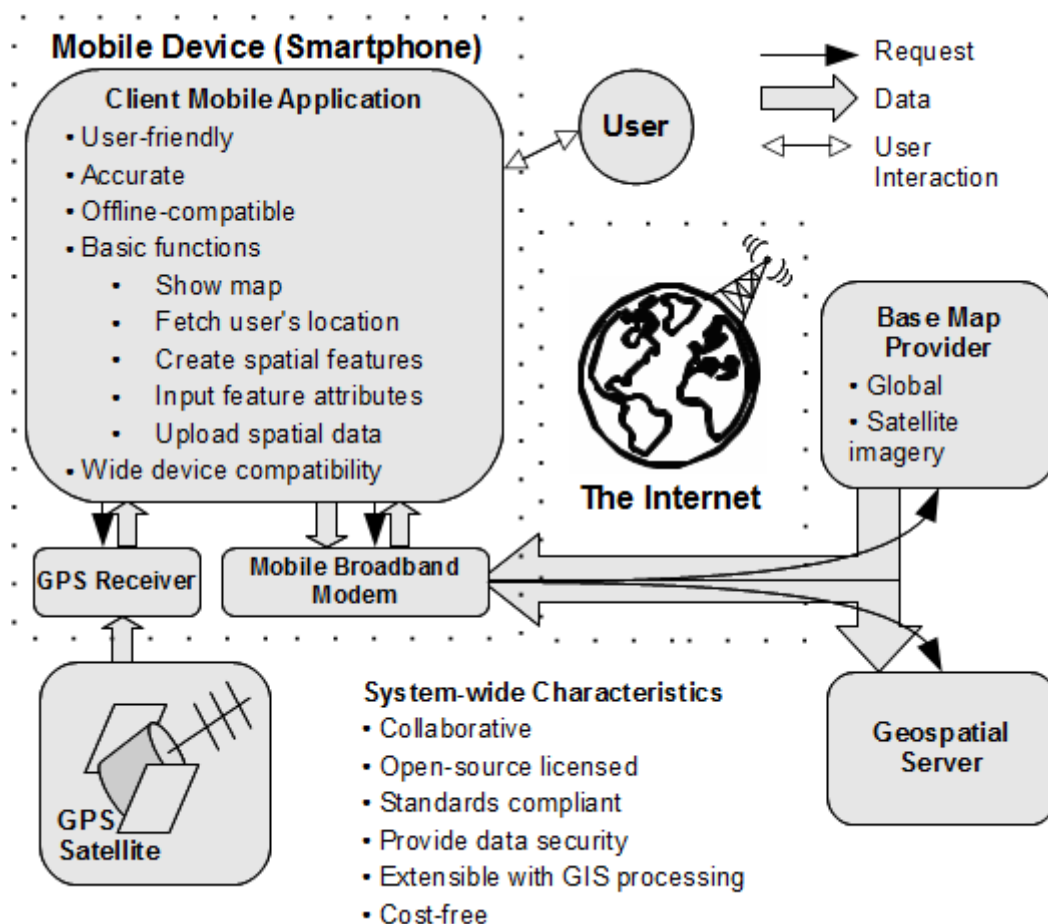


Figure 5: A proposed architecture for a free, open-source, mobile, emergency field data collection system. The system includes a mobile device that receives location data from GPS satellites and communicates via the Internet with a base map provider and a geospatial server.

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to a geospatial server using the device's integrated mobile broadband modem. Within the client application, a user's browsing of a map interface generates requests that are sent both to the geospatial server and to a base map provider. The latter responds with map or satellite images, which are overlaid by the map images received from the geospatial server.

The requirements 1-3 and 6 completely depend on the specific design of the client mobile application, as do requirements 4c-e. 4a-b are satisfied by the application, the geospatial server and the base map provider communicating with each other using the web connection, and by the use of the integrated GPS receiver. Requirement 5 and system characteristic D above could be implemented mostly within the client mobile application or mostly on the geospatial server or, as it is presented in Figure 5, as system-wide characteristics implemented on both together. System characteristics A to C are also considered system-wide, each part contributing to enable collaboration, each part being open-source and each part being standards compliant.

In addition to the requirements and system characteristics given in the previous section, the proposed architecture adds “cost free” as a system-wide characteristic, since most open-source licenses actually allow placing a cost on the software. Crucially for making the system useful in an international context, the base map provider is also required to have a global coverage of its maps.

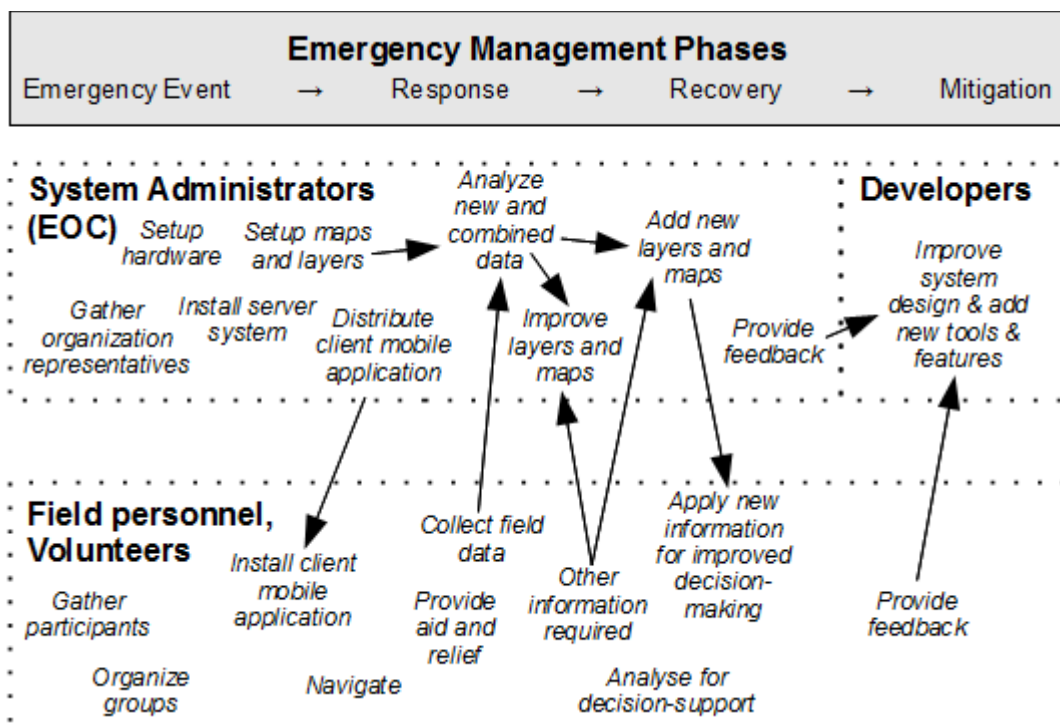


Figure 6: A dynamic and loosely ordered task flow based on the proposed architecture for an emergency field data collection system in this report. Examples of expected tasks for the involved groups of administrators, developers and users are shown throughout the emergency management phases.

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Figure 6 illustrates the expected task flow for the system's users (field personnel and volunteers), administrators and developers, loosely ordered along the horizontal axis that represents the progression of an emergency or disaster and its emergency management phases. Any single task may occur during any phase and any number of times. Some tasks, such as field data collection, are expected to be performed continuously after they are initiated. The arrows signify a cause-and-effect-like relationship between the connected tasks.

To give a brief explanation of the task flow in Figure 6, as the emergency event is observed, participating organizations appoint representatives to join the EOC as administrators. They also advertise and call for volunteers to join the rest of their field personnel in organizing response groups.

As soon as the EOC has set up the server hardware and installed the emergency field data collection system the client mobile application can be distributed, along with connection details, to all users with compatible smartphone devices who then install it. It can immediately be used to navigate as the groups proceed to provide aid and relief.

After the administrators finished installing the system, they start creating maps and layers with the spatial data publishing software of the geospatial server (Figure 3). This includes creating connections with remote data sources and otherwise gathering relevant data from the participating organizations. An important part of creating map layers is to design the data models for collection – what features are to be recorded and which of their physical and non-physical attributes should be used to describe and differentiate them? Another important part is to design the symbology of map layers to maximize the users' understanding and use of the information provided.

Because of new data being collected by users and because administrators have integrated data sets from different sources, analyses of new and combined data sets can yield interesting new information that administrators can use to both improve current maps and layers and to create new ones. Such improvements and additions may also be prompted by new or changed information requirement by the users.

With each addition and improvement the users can apply more and better information to their decision-making process, which has also been supported throughout the emergency phases by GIS processing tools available in the system.

To conclude, as the emergency management transitions into the mitigation phase in preparation of the next disaster, users and administrators alike provide feedback to the system's developer community so that they can further expand, improve or otherwise change the system for the better.

4. Case Study – Development of an emergency field data collection system

Next, an implementation of the emergency field data collection architecture described above is detailed. Its server-side software as well as the main components of EDCA, the developed mobile application, are outlined. The tools used for EDCA's development

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and relevant design specifications are addressed, but specific code or instructions for users and administrators are not included. For the latter, see Appendix 4.

Due to time constraints EDCA does not represent a complete implementation, incorporating all desired features, but rather a feasible sub-set within the scope of this thesis project.

Further, for investigating the usefulness of the system implementation, field trials were carried out, the methodology and results of which are presented in section 4.4.

4.1. Components

The composition of the case study implementation is presented in Figure 7. It is based on the architecture design of Figure 5, and shows the specific software and services used and the interactions that occur between components. In short, the system utilizes an application developed for Google's Android mobile platform, with supporting libraries to e.g. access the Google Maps API (Google Developers 2013) service as a base map provider. EDCA, which fetches the user's location using the smartphone's integrated GPS receiver, also uploads data to and downloads map images from the geospatial server. Each component of the implementation is described in more detail in

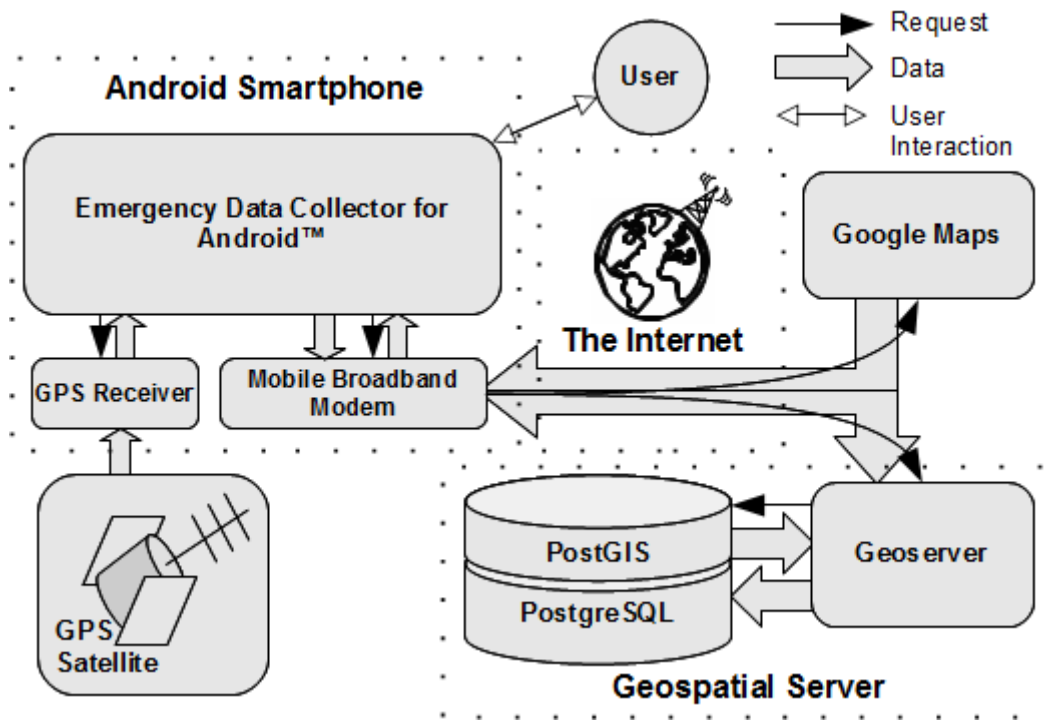


Figure 7: A case study implementation of a proposed architecture for a free, open-source, emergency field data collection system. It uses an Android smartphone and its GPS receiver with a custom application to send spatial data to a geospatial server. The geospatial server consists of GeoServer (2013) using PostGIS (2013) with PostgreSQL (2013) as the DBMS. The application also receives maps from both the geospatial server and Google Maps (Google Developers 2013).

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the following sections. Regarding the relevant standards used in the implementation, see Table 3 in section 2.4.3. GML and client-side WMS and WFS are used in EDCA. The components of the geospatial server implements SFS and SLD and the server-side of WMS and WFS.

4.1.1. Mobile Platform

The OS selected for EDCA's development was Google's Android platform, for a number of reasons:

- Openness – its API is licensed with the Apache License 2.0 that allows free and open distribution of the source code (Android Developers 2013a).
- Reach – Android had a market share of about half in 2011 and was forecasted to have more than half over the next few years according to the International Data Corporation (IDC, 2012). Lately, during the third quarter of 2013, the IDC reported a market share of 81 % for Android (IDC, 2013).
- Forward compatibility – Android is developed to keep applications forward compatible (Android Developers 2013b), that is, applications developed for an older or current version (API level) of the OS will likely work also in future versions of Android, prolonging EDCA's lifetime.
- Lastly, but importantly, the author had previous familiarity with the Java programming language that is used for developing Android applications and had easy access to devices on which to test the application.

Table 5: Distribution of Android API versions on mobile devices which visited the Google Play Store during the 14-day period prior to 2013-08-01 (Android Developers, 2013d). Distributions smaller than 0.1 % are omitted. Adapted from work created and shared by the Android Open Source Project (<http://code.google.com/policies.html>) and used according to terms described in the Creative Commons 2.5 Attribution License (<http://creativecommons.org/licenses/by/2.5/>).

Version	Codename	API level	Distribution
1.6	Donut	4	0.1 %
2.1	Eclair	7	1.2 %
2.2	Froyo	8	2.5 %
2.3 – 2.3.2	Gingerbread	9	0.1 %
2.3.3 – 2.3.7		10	33.0 %
3.2	Honeycomb	13	0.1 %
4.0.3 – 4.0.4	Ice Cream Sandwich	15	22.5 %
4.1.x	Jelly Bean	16	34.0 %
4.2.x		17	6.5 %

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The data in Table 5 should not be interpreted as the complete picture of which Android versions that are in use. There is no guarantee that the devices that visited the “Google Play Store” (Google's official application marketplace for Android devices) are a representative sample of all Android users. Regardless, the broad majority of the versions for which EDCA might be downloaded are clearly supported.

When developing applications for the Android platform, the recommended and most popular integrated development environment (IDE) is Eclipse with the Android Development Tools (ADT; Goadrich and Rogers 2011). The ADT extends Eclipse with a graphical UI design tool, Android debugging, application testing on virtual and physical devices, and digital signing of the applications among other things. In order to utilize these benefits EDCA was developed on a PC with the Eclipse IDE and the ADT.

The Android API uses XML files to define an application's graphical layout separately from the code (Android Developers 2013e). It uses another specific XML file called a “manifest” to declare its version, components and application permissions within the system etc.

Code-wise, an application has four main components, namely Activities, Services, Broadcast receivers and Content providers. Usually an Activity represents a screen with a UI, they are the components that users interact with. Services run in the background to perform tasks and keep track of information that should persist independently of what screen (Activity) the user is interacting with. For example, a service that is e.g. playing music may keep running after the user left the application. Broadcast receivers monitor announcements from the system, such as the device battery running low, or from other applications. They can also issue their own to notify other applications of important events. The fourth component type, Content providers, provide access to any type of storage location such local file storage, web locations or databases.

In addition to the core Android API, Google provides the Google Play services, a kind of system application which includes a lot of useful tools for developers and can be automatically updated without relying on the device manufacturers sending major Android updates to their devices. Google Play services gives advantages for application developers but, unfortunately, detracts from Android's openness argument as it is a proprietary package that makes applications dependent on Google itself (Amadeo 2013).

The main source of information and for learning about Android development was the Android Developers website (<http://developer.android.com>), which provides design guidelines, tutorials, best practises etc., and is the authoritative reference regarding the Android API. Online forums or question-and-answer sites such as Stack Overflow (<http://www.stackoverflow.com>) were also of great benefit during development.

4.1.2. Base Map Provider & Supporting Libraries

There exist several solutions for displaying maps in Android. With the development of smartphone web browsers, it is becoming increasingly convenient to use web capabilities designed for PC browsers also on smartphones, including Android devices.

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Thus, future capabilities of smartphones and more powerful web map applications (e.g. using HTML 5) may reduce the future need for native smartphone web applications. For now, however, for more advanced tasks native applications that are tailored for smaller touch-screens may be the better option, e.g. with potentially better user interfaces, offline-capabilities and access to device features (Ballve 2013).

For native applications, the Google Play services API mentioned above offers access to the “Google Maps Android API v2”, which can be used to access Google Maps' maps, satellite images and other map-related services. While there are other providers such as the OpenStreetMap project described in section 2.3.1., Google Maps was selected due to the combination of its global coverage and access to satellite images. Also, using Google's own Maps application, map tiles can be stored locally and viewed without network connectivity.

In order to efficiently store geometry and convert geometric objects to and from a readable text format (known as Well Known Text; WKT), the JTS Topology suite (JTS 2013) was integrated in EDCA. This library is fast, written in Java, complies with the OGC SFS standard and is licensed under the LGPL, allowing it to be incorporated into EDCA without issues (see section 2.4.4.).

4.1.3. Geospatial Server

The geospatial server used for the project is the DBMS PostgreSQL, spatially extended with PostGIS and with GeoServer for publishing the spatial data. These components were considered suitable both because the author was already familiar with them, and because of their active open-source development.

PostgreSQL is released with a specific license called the “PostgreSQL License” (PostgreSQL 2013). It is a non-copyleft license that basically allows any type of use of its source code and protects the original developer from any liability. PostGIS (2013) and GeoServer (2013) are licensed under the GPL 2.0 license.

To set up the geospatial server, in short, required:

- installation of PostgreSQL, PostGIS and GeoServer,
- adding a spatial database in PostgreSQL,
- adding tables with a spatial column,
- adding a path (data store) to the PostGIS database in GeoServer,
- adding a workspace for the layers (compare to a folder in a file system),
- adding the previously created spatial tables as layers,
- and, finally, defining the layout and style of the added layers using SLD files.

GeoServer includes an integrated web server, making the combination of these three software systems a complete geospatial server system.

When creating tables and defining their columns and column data types, the

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administrator is, in effect, defining the spatial data model of the entire system. It is in this step that the types of features and what attributes should be recorded are determined. As the project matures, this data model will likely have to be amended continuously to suit the information requirements of its users (see Figure 6).

4.2. Features

For a detailed description of how EDCA works and how to use it, see the EDCA User Guide (Appendix 4). This section illustrates some of EDCA's features and features of the entire system that may not be obvious from the User Guide or that are of particular interest for emergency field data collection.

- Standards compliant and multi-sourced – EDCA can display maps and upload data to any standards compliant server, or even multiple servers simultaneously.
- Dynamic data model – new or edited map layers, e.g. with additional attribute columns, can be accessed by users simply by re-connecting with the server.
- Customizable symbology – multiple map layers may read the same spatial tables and apply layer-specific symbology, allowing the system administrators to better cater to the needs of diverse groups of users.
- Offline mode – Google Maps tiles can be downloaded for offline use, and data collection using the GPS device is always possible. If the geospatial server cannot be reached, the user can store collected data locally instead, waiting for a connection to become available.
- Cooperative feature delineation – since lines and polygons are formed by connecting point locations together, multiple users can collect points and, by sending the point coordinates to a single user, can combine their respective vertices into a complete feature.
- Input control – By paying attention to the data types of attribute columns, EDCA makes sure that user input has a valid format.
- Uploading clears local data – Features stored in EDCA are deleted when a user has uploaded data to the server, if successful, which ensures that no data can be uploaded twice.
- Accessible storage – Geometry is stored locally as WKT, making it freely accessible and human-readable as well as editable on the smartphone's external storage (e.g. the SD-card).

4.3. License

To benefit from previously described advantages of open-source licenses and in accordance with the aim of this project, EDCA is released under an open-source software license.

To make it easy to use EDCA and to understand what rights are granted by its license, it

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was decided to use one of the most common open-source licenses (Table 4). Specifically, the copyleft license GPL (version 3.0 or any later version) was selected to ensure that the emergency management community, including organizations without significant financial resources, can benefit from any and all improvements to EDCA. Without the reciprocal rights requirement of copyleft licenses, proprietary versions could arise and out-advertise the open-source product, effectively obscuring it from view.

In accordance with GPL v3, EDCA's source code is made available. How to access it is described in Appendix 1.

4.4. Field Trials

In response to the secondary aim of this project, field trials were held to evaluate EDCA and its applicability to emergency field data collection. While, for a number of possible reasons further discussed in the next chapter, there were very few participants in the trials, the methodology and their results are presented here as they are deemed valuable as practical demonstration and proof-of-concept.

4.4.1. Methodology

A hypothetical emergency was developed and described in an instructions and questionnaire document that was sent to potential respondents with an invitation to participate. The document (Appendix 3) included some background information about a hypothetical drought emergency, a field data collection assignment, server connection details and a questionnaire to respond to after completing the assignment.

Before inviting respondents, the implemented system was prepared with the geospatial server being set up according to the work flow described in section 4.1.3. For the field data collection assignment, three layers were created and published on the geospatial server.

The layers published were based on three spatial tables defined as shown in Table 6, with geometry types according to the data type of the “_geom” columns. The number, 4326, designates the spatial reference system, in this case the World Geodetic System 1984 (WGS 84), which is the reference system for GPS. Each recognized spatial reference system is given such a code by the European Petroleum Survey Group (EPSG). The “_id” column was an automatically incrementing identifier value that was not input by users. The “_name” and “_comment” columns, of which the comment column did not require input, let users input any text. The “_driedout” column signified whether or not the well or the watercourse represented were already dry, and users were required to input *true* or *false* (boolean). The “_reporttime” column let users input the time when the data were collected (EDCA suggests the current time). Lastly, the geometry was input using the device's GPS, by long-clicking on the map or by manually entering coordinates (see Appendix 4).

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Table 6: The design of the spatial tables that were published as web map layers, to use during field trials of the Emergency Data Collector for Android mobile application. It shows the table names, the column names, the column data types and whether the columns are allowed to be empty.

Table	Column	Data type	Empty OK
well	well_id	Integer	No
	well_name	Text	No
	well_driedout	Boolean	No
	well_comment	Text	Yes
	well_reporttime	Time (yyyy-MM-dd hh:mm:ss)	No
	well_geom	Geometry (Point, 4326)	Yes
watercourse	watercourse_id	Integer	No
	watercourse_name	Text	No
	watercourse_driedout	Boolean	No
	watercourse_comment	Text	Yes
	watercourse_reporttime	Time (yyyy-MM-dd hh:mm:ss)	No
	watercourse_geom	Geometry (MultiLineString, 4326)	Yes
drymeadow	drymeadow_id	Integer	No
	drymeadow_name	Text	No
	drymeadow_comment	Text	Yes
	drymeadow_reporttime	Time (yyyy-MM-dd hh:mm:ss)	No
	drymeadow_geom	Geometry (MultiPolygon, 4326)	Yes

Figure 8 shows the styling of the three published layers, as they were set up in GeoServer. The value in the “_driedout” column determined whether well points and watercourse lines were displayed with red or blue colour.



Figure 8: The symbology of the three layers used for the Emergency Data Collector for Android (EDCA) field trials. Features in each layer are shown together as a map example.

In the assignment given to the field trial participants, they were asked to record one feature for each of the three drought-related layers, i.e. a well (point), a watercourse (line) and a dry meadow (polygon). They were also required to input made-up attributes for the features arbitrarily, while noting how much time they spent using EDCA.

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Upon completing (or abandoning) the assignment, they were asked to fill out a short questionnaire about it (Appendix 3). It included some background questions such as what device they used, some questions about the assignment such as whether or not it was completed successfully, some about EDCA such as how to improve it and a final optional question for further comments.

After the server preparation was finished, during a period of approximately two weeks, more than 250 invitations to the field trials were sent through e-mail, web forms and through an open invitation on a social media website for OGC standards users. The respondents were given 1-3 weeks to respond, and a few days after the deadline a reminder was sent to the respondents who had agreed to participate but hadn't yet replied. Invitations included an address to a web page hosted on the geospatial server (Appendix 2), that offered visitors to download the EDCA install package (the Android .apk file) and the most recent version of the User Guide (Appendix 4), which has received occasional revisions throughout the project.

Primarily, three groups of respondents were targeted with the invitations:

- disaster relief and aid organizations,
- teachers and co-students of the author in the Department of Physical Geography and Ecosystems Science of Lund University, Sweden,
- and acquaintances and non-acquainted GIS professionals.

Some notable examples of organizations that were contacted are:

- SIDA – Swedish International Development Cooperation Agency.
- UNICEF – United Nations Children's Fund.
- MSB – Swedish Civil Contingencies Agency.
- Save the Children.
- CNDS – Centre for Natural Disaster Science. A national knowledge-centre, run jointly by Uppsala and Karlstad Universities and the Swedish National Defence College.
- FEMA – United States' Federal Emergency Management Agency.
- Red Cross (Sweden).
- VOAD – United States' National and State “Voluntary Organizations Active in Disaster”.
- Doctors Without Borders (Sweden).
- The World Bank.
- Amnesty International (Sweden).
- WHO – The World Health Organization.

Due to the small number of responses, no statistical analysis was deemed useful. The responses are therefore simply described below to report the results of the field trials.

4.4.2. Results

In total, 26 invitations received replies. Out of these, seventeen invitations were declined, seven because the respondents did not own compatible Android smartphones.

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The other ten respondents either forwarded the invitation or referred to other organizations or websites, which yielded at least 190 new respondents.

Of the 9 respondents that initially indicated an interest in participating; two did not participate despite the reminder, one could not get access to a compatible device and two tried to complete the assignment but met with difficulties and never finished or filled out the questionnaire. Both of the two latter respondents reported, at different stages in the field trials work flow, that they were unable to determine how to proceed. Their comments did not conclusively rule out device incompatibility as the origin of the issues, but indicated that particular functions of EDCA may not be obvious enough for users to easily discover.

Among the remaining four respondents who participated and filled out the questionnaire, three answered that they had previous experience with GIS and none of them had previously participated in “emergency/disaster response or recovery operations”. The smartphone devices used by the participants were all of different models and used different versions of the Android platform, ranging from 2.3.4 to 4.3.

For the questions regarding the assignment (Questions 6 to 8, Appendix 3), three participants answered that they had read some or all of the User Guide, and that it was helpful when learning how to use EDCA. Three participants completed the assignment successfully, including the participant who had not read the User Guide. The participant who did not complete the assignment had successfully added a point feature but had for unknown reasons not been able to add multiple locations to form line or polygon features. The time spent using EDCA differed greatly, between one participant indicating that 3 minutes and 40 seconds was used and another participant reporting 1 hour and 20 minutes. The other two both answered that EDCA was used for 30 minutes. These answers are also displayed in Table 7, which lists the answers to Questions 6 to 10, except 7b.

Table 7: Questionnaire answers by the four field trial participants to Questions 6 to 10, except 7b. Questions a shortened, for the actual questions see Appendix 3.

	6. Read User Guide?	6b. User Guide found helpful?	7. Completed assignment?	8. Time using EDCA?	9. Easy to learn?	10. Easy to use?
#1	Yes	Yes	Yes	3 min 40 s	Yes	Yes
#2	Yes	Yes	No	30 min	No	No
#3	Yes	Yes	Yes	1 h 20 min	No	Yes
#4	No	–	Yes	30 min	Yes	Yes

The answers to questions 9 and 10, concerning the user-friendliness of EDCA, show that half of the participants found it easy to learn as well as easy to use, including the participant who did not read the User Guide. Of the other two, who did not find it easy to learn, the participant who had completed the assignment indicated that it was afterwards considered easy to use (Table 7).

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Questions 11 and 12 asked the participants for suggestions on how to improve EDCA and gave them an opportunity to leave further comments. Their suggestions, listed below, included both improvements to the user interface for user-friendliness and additional features that would be useful:

- Users should get a visual confirmation upon successfully adding a location.
- Layer selection should be accessible from the map Activity, to avoid unnecessary navigation.
- The fetching of WMS map images from the geospatial server lags behind the base map and should be improved for better responsiveness.
- Data should be stored when a user switches the layer to collect data for, so that users are not required to upload all data before switching.
- It should be possible to use the smartphone GPS receiver for adding locations.
- The base maps (Google Maps) should be available offline as support for data collection in areas without network connectivity.
- Data should be uploaded automatically when, after network connectivity issues, the device regains connection to the Internet.

As a general comment (Question 12), one participant stated that EDCA might be of use during field work for research, but also expressed concern whether it could work in areas without network connectivity.

5. Discussion

The aim of this thesis project was to develop a mobile application to act as a component of an emergency field data collection system, in which each software component is released under an open-source type of license. Secondly, it was to evaluate its applicability and find out how to improve it from an emergency field data collection perspective.

A system architecture was designed based on requirements and lessons learned through a literature study. As a case study, the Emergency Data Collector for Android (EDCA) mobile application was developed and together with a geospatial server it was used to set up an implementation of the designed architecture, upon which field trials were held.

5.1. Architecture Design

One of the basic premises for this project was the choice of using smartphones for data collection, mainly because of their advanced computing power and their ubiquity, making them the first component of the architecture. Because of the field workers' need for up-to-date information about the current emergency situation, a remote connection to a central point, such as the EOC, where map data from multiple organizations are accessible was required. This demanded some form of geospatial server.

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The choice to separate the source of base maps from the geospatial server to a separate base map provider was less obvious. There may be organizations involved in emergency management which are themselves producers of spatial data that could form adequate base maps for their users, in which case the base maps could also be offered on the geospatial server. In order to accommodate for the expected majority of cases, where locally produced and owned base maps are not available or are not adequately detailed or updated, and because of the relatively large strain it would put on the geospatial server, it was decided to use an external base map provider.

5.2. Implementation

The motivations for selecting each specific component for the implementation of the system architecture is described in the Case Study chapter above. Still, there are a number of design considerations that merit further discussion.

The use of WMS requests in EDCA, to return the data from the geospatial server as map images instead of returning the actual data which would be the case if using WFS, is one such consideration. The main advantages to WMS compared to WFS are, firstly, that even as the amount of features or map details become very large, the bandwidth and consequently time and battery use for transferring one WMS map image remains practically the same. Secondly, by fetching WMS images from the geospatial server, control over map symbology can be left to the system administrators (unless a client would let users supply their own symbology for each map request). This spares work for EDCA users and ensures that users can be provided with consistent and efficient map symbologies. Thirdly, the fetching and displaying of WMS images required significantly less effort during development. Fourth, providing clients with map images directly adds a measure of security by not distributing the actual spatial data.

On the other hand, fetching the data using WFS could potentially have enabled more personalized symbology. It could also have simplified future extensions of EDCA with GIS processing tools that may need to analyse geometries stored on the geospatial server, or with allowing editing of server data. Lastly, using WFS to download and display data in EDCA would have been done once, or occasionally, when the user requested an update of the current emergency state. Between such updates, clients would not communicate with the server except for uploading data. The implications of sending an updated WMS image to each user – every time they pan or zoom in the map – is that a large number of users, during peak usage, could put an enormous strain on the geospatial server compared to WFS. This could perhaps outweigh the comparably smaller sizes of WMS map images.

Another design consideration was whether or not to store map tiles on the smartphone's external storage. Storing map tiles would greatly increase the utility of offline mode, while demanding more storage space. At the time when the project was started, developing map tile storage was considered to be too tedious, but after the release of version 2 of the Google Maps Android API (Google Developers 2013) it may be easier to implement, making it an interesting possibility.

Furthermore, in order to convey to the user a sense of connectedness with the geospatial

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server a “connected-disconnected” model was chosen for EDCA's connection management. The model was considered to lend itself well to situations of intermittent network connectivity, informing the user of the current state of the connection. However, both the model and its implementation is now considered suboptimal. Since EDCA does not continuously monitor the connection, so as to not waste computation resources and battery charge, the “connected” concept is not actually accurate. EDCA simply “disconnects” when, for any reason, it fails to communicate with the geospatial server. Also, it does not automatically “re-connect” when the server becomes available. Thus an operation based model would be more accurate, letting users actively “fetch” server information, “request” maps or data and “post” spatial data to insert into the database. The latter model would also avoid giving users false expectations on EDCA's server connection management.

5.3. The Field Trials

While the field trials that were held provide a proof-of-concept, there are many issues to address concerning the methodology and the interpretation of their results. First, the very small number of responses is an obvious disadvantage. That only about 10 % of the sent invitations received replies is maybe not that surprising. However, if the respondents that did reply are any indication, the reasons for not participating should to a large degree include not owning a smartphone or a smartphone running Android.

Of those that referred the invitation to other people, suggested other websites in their reply and those that did not reply at all, the reasons may include the above reason as well as a lack of time or interest to participate. They may also not consider themselves familiar enough with installing and using smartphone applications.

Some ways to increase the number of participants could be to, first, send a larger number of invitations. Second, the time before the participation deadline could have been longer, allowing people that were very busy during the participation period to better plan ahead. Third, for the respondents based in Sweden, the time of year when the invitations were sent represented the end of the vacation period and/or the first weeks of coming back to work or school. This is usually a very busy time, so holding the field trials at another time of year, preferably mid-semester, could have allowed a larger portion of the respondents to participate. Lastly, since at least two respondents tried to participate but met with problems and did not fill out the questionnaire, more thorough and pedagogic instructions and an improved learnability of the application could have made these respondents finish the assignment. There may be an additional number of respondents that fall under this category but that did not reply or notify the author of their difficulties.

As for the results of the questionnaire, the fact that all the participants had different smartphone models and Android versions, and that the assignment was completed successfully by three of them, provides an initial indication that EDCA is compatible with a wide range of devices.

Regarding EDCA's general user-friendliness, the results show that the participants had very different experiences. It ranged from Participant #4 in Table 7, who found EDCA

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easy to learn and easy to use (indicating learnability and efficiency), without having read the User Guide, to Participant #2 who did not find it easy to learn nor easy to use, despite having read the User Guide and found it helpful. Neither respondent #2 or #3 found it easy to learn how to use EDCA, but both read the User Guide and found it helpful to the point that one of them found EDCA easy to use after participating in the field trials. This supports the position (illustrated by Clark et al. 2010) that user instructions and tutorials are very important when introducing tools such as mobile GIS applications to volunteers and emergency field personnel. The large variance in the time spent using EDCA could further indicate how the learning experience can differ between users. It should be noted however that these times represent how long it took the participants to complete the assignment as *first-time users* and not the time it would ideally take when already familiar with EDCA. Also, the small number of participants make it impossible to draw strong conclusions about an average time. Additionally, users may have interpreted the instructions differently and thus some may have included time spent moving between locations or reading the User Guide.

In total, the field trials with their four participants, of which three completed the assignment successfully, can be considered to provide an adequate proof-of-concept and illustrate EDCA's effectiveness. They show that EDCA can be applied as an emergency field data collection tool. Nonetheless, more extensive trials with a greater number of participants, also including participants with prior experience from emergency response and recovery operations, would be necessary to make a more conclusive evaluation.

For future development of the system, the user feedback provided several important points for improvement, with a focus on user-friendliness and additional features to simplify the user task flow. The fact that a few of the suggestions concerned features that were already implemented (compare the suggestions to the list of features in section 4.2. and the User Guide in Appendix 4), again implies that some functions may not be obvious enough to the users, and that user-friendliness and the User Guide could use further improvement.

5.4. Satisfaction of Requirements

Noting that the field trials indicated that EDCA can be applied to emergency field data collection and that one participant stated expressly that it could be useful during field work, how well does the system architecture match the listed requirements and how well does the implementation match the architecture?

The architecture presented in Figure 5 encompass all listed requirements with their distribution among components described in section 3.2. The global coverage of the base map provider and all components being cost free were two additional characteristics of the designed architecture.

Comparing the architecture with the case study implementation in Figure 7 and the description of its components and features in chapter 4, it can be found that the implemented system matches the architecture well. Some characteristics are missing, however, and some may not be so obviously implemented.

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The user-friendliness of EDCA, as discussed above, can be questioned. Especially so in the light of the field trials results showing that two out of the four participants did not find EDCA easy to learn and that one focus of their suggestions concerned user-friendliness. But considering that three participants completed the assignment successfully and that user-friendliness could be rated on a continuous scale with, in practise, infinite room for improvement, EDCA can be said to have a basic level of user-friendliness but to need further improvement to excel in this area.

With the current level of input control in EDCA, and positional accuracy of modern smartphone GPS receivers, EDCA clearly has a potential for producing adequately accurate data for many emergency management needs. There is a risk though, noted by Boulette et al. (2011), that GPS accuracy in general may decrease in the coming years due to increased solar activity. Their research could counter these effects somewhat by using GPS error corrections sent through mobile communications networks, but such corrections are not implemented in this project. Mapping certain types of spatial data, such as sub-surface infrastructure (water- or sewage pipes, power lines, etc.), may also require a better accuracy than that offered by current smartphones. For such data, there is a need to map these facilities before disasters occur. When accurately mapped ahead of time, the smartphone GPS accuracy may be good enough to locate specific facilities with support from the pre-disaster maps. For the thematic accuracy, as with user-friendliness, there is room for further improvements of the input control to increase accuracy in the collected data.

EDCA can be used for data collection in areas without network connectivity by storing spatial data locally and uploading them when access to the Internet is available. A deficiency, however, is that the satellite images provided by the Google Maps base map provider cannot be accessed when offline, and neither can the geospatial server be reached. This leaves the users unable to view the current state of the emergency and means that while the system works without network connectivity, this requirement is only partially satisfied.

All of the basic functionality (requirements 4a-e) is included in EDCA and, through its support for point-, line- and polygon geometry and feature attributes (requirements 4c-d), it is suitable for many types of required emergency data layers, such as those identified by Mansourian (2005). It works on a wide range of devices, as presented in section 4.1.1. and supported by the results of the field trials, and it is possible to extend EDCA with additional GIS processing features according to requirement 5. Concerning the latter, as discussed above, using WFS for displaying server data would have simplified development of such extensions as many uses may require downloading spatial data through WFS in any case.

Furthermore, collaboration between emergency organizations can be facilitated by the use of a single, common, system for emergency field data collection. The possibility to publish layers from multiple sources on the same geospatial server and the ability to view and collect data for layers on multiple geospatial servers using the same application, together provide options for adapting the system to specific groups of organizations. Also, as mentioned above, a feature of e.g. GeoServer allows server

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administrators to provide user groups with map symbology customized to their specific needs, which can be very important for conveying information efficiently through maps (see Charvat et al. 2008).

As for openness, each component is released with an open-source license except the base map provider. Google's API for accessing Google Maps on Android is proprietary, as is the actual map service and its data. It is cost-free, but to a certain extent. The use of Google Maps is a compromise that favoured the map content and the easy-to-implement API before openness. At the present time, Google's service terms do not preclude any emergency organization from applying this system, but if the number of users (or rather, the number of map images fetched per day) becomes very large, Google could potentially charge a fee for continued use of the service.

By using standards compliant components for the geospatial server, such as GeoServer which is the reference implementation of WFS, and by using the OGC standard interfaces WMS and WFS in EDCA, the implementation adheres well to applicable standards. It cannot be claimed to fully implement each relevant standard issued by both the ISO and the OGC, but the goal of achieving interoperability is met, at least in the sense that EDCA can be used with many different types of geospatial servers and each server component (treating PostGIS and PostgreSQL as a single component) could be used with other GIS software or in other similar systems. That is, the system components are flexible with regards to combining with other components.

A characteristic of the architecture that was not implemented is that it should provide data security. In the current implementation, EDCA has no way for users to supply credentials. The geospatial server supports multiple types of authentication (GeoServer 2013) and the author speculates that EDCA could fairly easily be extended to support user management as well. However, information dissemination, as previously mentioned, could be considered a higher priority in life threatening situations. Thus, since it was not possible, within the scope of this project, to include all desired features during development, the data security characteristic was not implemented. A mitigating factor is that EDCA, in line with an emergency management principle cited by Charvat et al. (2008), does not allow users to edit or download data from the geospatial server, only the insertion of new records. This does provide a certain level of data security.

Regarding the two additional characteristics of the architecture, the implementation is suitable for use globally, except on the extreme latitudes. Google Maps uses the Pseudo Spherical Mercator projection (its EPSG code is 3857) as spatial reference system (SRS), as does other web maps such as OpenStreetMap and Microsoft's Bing Maps. The Pseudo Spherical Mercator is greatly distorted on high latitudes and Google's map service only offers map images up to approximately ± 85 degrees. With so few people living at greater latitudes than these, disasters and catastrophes requiring traditional emergency management organizations are unlikely. Thus, the system's coverage is enough to consider it globally applicable. The cost-free characteristic of the architecture is also considered successfully implemented, as each component of the architecture is free of cost, except, under certain circumstances, the Google Maps service as discussed above.

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Although the above discussion shows that the architecture satisfies the identified requirements and that the implementation matches the architecture quite well, how does that translate into the handling of such challenges with using GIS and spatial data in emergencies as those discussed in section 2.2.1?

The challenge in getting precise GPS positions in difficult terrain such as urban rubble, discussed by Kevani (2003) can be side-stepped by the use of satellite images or other detailed base maps, enabling users to identify their location on the map themselves. Assuming that the area in question is still recognizable, users can manually add their location in EDCA by long-clicking on the map. Since users can enter coordinates manually too, it is possible to use more powerful GPS receiver devices to assist in such areas.

The challenging environment of critical but vulnerable communications networks (Kevani 2003; Comfort and Haase 2006) is tackled by being able to collect data without network connectivity and then to upload them as a connection becomes available again. Although the system handles these two challenges well in separation, they remain significant challenges. Especially so if network connectivity is unavailable in an area that also has difficult terrain for GPS localization. The users may in those cases not be able to acquire accurate positions through GPS, and nor would they be able to rely on satellite images for support, as they cannot be viewed while offline.

Two challenges that were specifically targeted with the choice to rely on private smartphones are the large demands on user skills, systems and equipment when using spatial data for emergency management and the frequent lack of resources in participating organizations (e.g. Cutter 2003; Mansourian 2005). Being a cost-free system that uses devices already owned by the users themselves (which should guarantee a greater familiarity and skill), these should not be important issues when using the proposed system. While the system demands less of its users and is nominally free of cost, the skills required to install and manage the system, however, may be equal to or even greater than comparable systems. Considering that none of the open-source components come with technical assistance or support (other than voluntary help from often quite vibrant communities on the Internet), the system may require either in-house personnel with a large skill set, or it may force organizations to pay third parties for support and assistance.

The features of the system which facilitate collaboration discussed above, are a big step toward overcoming the challenges with coordination and integration of data from multiple sources discussed by Kevani (2003) and Mansourian (2005). These together with the implementation of OGC standards help to reduce problems with GIS and data incompatibilities, but being a strictly technological system, it does not address the cultural, institutional, financial and legal barriers to sharing spatial data identified by the INSPIRE (2003) consultation. Nor does it address the challenges with producing complete and applicable spatial data sets or providing them with adequate documentation, except perhaps through assisting in collecting *more* data.

5.5. Strengths

Based on the literature study it is evident that there are many types of systems which enable distributed collection and centralized storage of geographic data in different contexts (e.g. Montoya 2003; Aanensen et al. 2009; EL-Gamily et al. 2010; White et al. 2011). Some of them (e.g. Aanensen et al. 2009; White et al. 2011) employ smartphone applications for Android. Some are also open-source. There are both open-source and proprietary mobile GIS applications that are rapidly moving forward with more advanced GIS processing features, including field data collection and even editing capabilities.

The major strength of the EDCA App and the system implemented is its potential for collaboration through its combination of openness, mobility, standards compliance, multi-source capability and adaptability. It does not, as some mobile data collection systems, rely on project-specific architectures or require the developer to issue custom versions of the system to tailor for any specific scenario. Instead, it puts the power in the hands of the administrators, which can adapt the system to the needs of their specific users, groups of users or for the public. In fact, while the system was developed with emergency field data collection in mind, through its flexibility, it is not strictly limited to such an application.

Putting the system in the context of an SDI (Figure 2) for emergency management, it embodies the technology component. Some of the characteristics that stand out as especially interesting include:

- Relatively low user skills requirements.
- User and producer roles tend to blend together.
- Regulations and partnerships regarding technology are made easier by the free and open-source nature of the system. License issues and software costs are non-existent as are client-side hardware costs when the users use their own smartphones.
- If user authorization would be implemented in EDCA, the server-side components would allow setting policies for access, use and production.
- By using a single system, that also provides input control, data standards can more easily be adhered to and data heterogeneity can be reduced.

5.6. Improvements and Future Research

Through the literature study, the field trials and the experience gained while developing and using EDCA, a number of suggestions on how to improve EDCA and the system have arisen, in addition to those received from the field trials participants. These are ideas for improving the system and EDCA itself, but they are also, in a wider context, related to areas of future research concerning mobile emergency field data collection.

User-friendliness has been identified as a particularly important characteristic in order to achieve wide-spread adoption and use of an emergency field data collection system.

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This area has not received enough attention from researchers in the specific context of emergency management, but is otherwise developing rapidly with the spread of touch-screen smartphones to each corner of the world. Doyle et al. (2010), for example, present research with multi-modal input to improve user-friendliness and efficiency. That is, they provide users with multiple choices of input techniques, such as using speech, pens, eye-tracking etc. to e.g. simplify input whilst moving and catering to differences in user preferences or physical capabilities. Adding e.g. speech recognition for a more flexible user interface could mean a significant such improvement. Other ideas for improving the user-friendliness of EDCA include:

- in-App tutorial screens that can be disabled when no longer needed,
- and a widgetization of the add location functionality to allow fast access and response. This would mean putting a small user interface on a home screen that could be accessed without first starting EDCA the usual way.

While it has not been a priority in the present project, future research should also view administrator-friendliness as a relevant concept that is worth more attention. Unless an organization has personnel with the required skills, open-source and cost free systems can be virtually unavailable to resource poor communities nonetheless.

Thematic accuracy was discussed in the System Design chapter, and enumerations were mentioned as a way to improve it. Further development of EDCA should better address thematic accuracy by providing attribute input control using enumerations, so that some entered data can be standardized through multiple-choice lists.

The difficulties with data heterogeneity are perhaps greatest when using crowd-sourced information collected from sources such as Twitter as described by Barbier et al. (2012). Regardless, the use and integration of more types of data from new sources is and should remain an important research area in emergency management. An idea for such an improvement to EDCA would be to add the possibility of sending and parsing locations via SMS to enable cooperative feature creation. This would simplify the creation of lines and polygons for a group of users, and could also be used to enable people without compatible Android smartphones to help out, assuming they can acquire the correct position some other way (e.g. using dedicated GPS devices or using web maps etc.). Further, passive data collection using integrated smartphone sensors, such as that developed by White et al. (2011) could also enable novel types of data to be integrated.

Enabling a larger number of people to participate in emergency field data collection is one of the more long-term goals of this research. More users inevitably puts more strain on server systems, which causes the performance, reliability and security of the system to become increasingly important.

Geospatial server performance is developing rapidly outside the realm of emergency management, but improvements benefit this area as well. Making use of the improvements requires that the server components are evaluated, compared and replaced if needed. An unofficial developer community benchmark that compared the WMS performance of major map servers indicated that, performance-wise, MapServer

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may be a candidate for replacing GeoServer (McKenna 2011) as the spatial data publishing software component of the geospatial server.

Reliability includes being able to use the system while offline. EDCA's current offline-capabilities could be strengthened by automatically caching map tiles (storing map images), both from the base map provider and the geospatial server, so that they can be viewed without network connectivity. Google Maps does not support automatic tile caching so this solution would require changing base map provider, or using a combination, keeping Google Maps for access to the global satellite coverage. To stop relying on the proprietary Google Maps API would give the additional benefit of increasing the system's general openness.

Data security is already well implemented in the components of the geospatial server, so adding user authorization support to EDCA would provide a straight-forward solution for adding data security to the system.

Future research should continue working on device compatibility, perhaps using solutions such as that presented by Chen et al. (2012). It should include developing as efficient data models as possible to improve semantic interoperability, a unified understanding of common concepts and to reduce the response time required for setting up emergency management systems for a wide range of scenarios and user groups. Lastly, it should try to anticipate technological advances in the near future and start solving tomorrow's problems today. It should be visionary.

6. Conclusions

The field trials, mainly due to difficulties with gathering participants, could not conclusively evaluate EDCA and the system's applicability for emergency field data collection. Still, they proved that it was possible to make use of EDCA and the system for an emergency field data collection task and they generated useful suggestions and insights on how to improve EDCA.

Considering that a mobile application was successfully developed, that it was possible to use it for its intended purpose and that EDCA and each component of the implementation is released under an open-source license, the main aim of the project was reached, with a reservation. The latter being that the base map provider, including the API used in EDCA to access it, is an exception that is not released as open-source, but that was selected as a compromise because of the usefulness of its map content and the less time-consuming development.

Separating the secondary aim into the evaluation of EDCA's applicability and the generation of improvement suggestions, the author concludes that the second part was reached using the field trials held. The first part failed, to a degree, since no definite conclusions about its applicability could be drawn. Regardless, the results indicated reason for optimism about the applicability of EDCA for emergency field data collection.

Kenny (2012) hypothesizes that developing means for communicating during

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emergencies and improving preparedness will provide substantial and affordable benefits to resource-poor communities. It is the author's hope that the mobile application, as an emergency communication system, will provide such benefits. Reaching resource-poor communities is a challenge that has not been addressed within the scope of this project, but with open-source development, the possibilities for both adapting and adopting the system are virtually endless.

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Appendix 1 – Source Code Access

The source for the mobile application developed during this thesis project can be accessed in the following ways:

- Visit the project's GitHub web page:
 - github.com/MattiasSp/EDCA
- E-mail the author at:
 - edca.contact@gmail.com

To access the latest version – or even contribute to its development – readers are referred primarily to the project's GitHub web page. As a secondary alternative, source requests can be sent to the provided e-mail address.

A static version of the application source code at the time of thesis publication is published on the Lund University website.

- Search for the thesis at the Lund University website:

<http://www.lunduniversity.lu.se/current-students/lu-student-theses-database>

Appendix 2 – Field Trials Download Web Page

<http://edca.zapto.org>

The Emergency Data Collector for Android™

Field Trials Download Page

Welcome to the field trials for the Emergency Data Collector for Android™ (EDCA). Use the following links to download the Android installation file (.apk) and the User Guide:

[Install EDCA](#)

[EDCA User Guide](#)

[Field Trials Instructions and Questionnaire](#)

Right-click (long-click on Android devices) and choose "Save link as" or similar to save the files to your device.



Appendix 3 – Field Trials Instructions and Questionnaire



Lund University
Mattias Spångmyr
mattias.spangmyr.217@student.lu.se
2013-08-05

Emergency Data Collection Assignment and Questionnaire

The following is a description of a hypothetical emergency situation in which You will be given a data collection assignment and, following that, You are asked to complete a questionnaire about the experience.

Requirements:

- Hand-held GPS equipped device running the Android operating system, version 2.2 (API level 8) or newer.
 - A device's version number can usually be found in the device “Settings” under the heading “About phone”. If you can not find the Android version number, consult the device manual.
- Watch or other device for measuring time.

Hypothetical emergency situation and assignment

A drought disaster has struck the region where You are. Droughts are uncommon in this area, so there has previously been little or no planning for such events. You are part of a recently recruited group of volunteers of mixed backgrounds and experience who own Android devices. The task you have been given is to map the status of water sources and areas at risk of wildfire.

The drought is still in its early stages with hot temperatures, declining water resources and an increasing risk of fires. Especially upwind open areas where fires could spread rapidly toward urban land are considered as requiring special attention, so mapping areas such as dry grass meadows could make e.g. inspections or the creation of firebreaks (the removal of combustible material, “fuel”, in lines to stop fires from crossing) more effective.

The Emergency Operation Centre (EOC) has just finished setting up a server to which all volunteers will upload collected data using a supplied mobile application for Android.

Your assignment is to find and report three hypothetical features of interest to the EOC. *Record the total time you spent using the application* in order to complete the assignment, from the moment you launch the application each time, until you put away your device.

The EOC has provided You with the following information to get the application and connect to the server:

- Download the Application and User Guide from this website:
 - <http://edca.zapto.org>
- Server connection details:
 - Use IP Address Mode: NO
 - Name: Arbitrary (choose any name)
 - Full Server Address: <http://edcaserver.zapto.org/geoserver>
 - Port: 9090
 - Workspace on the server: drymap

For the three hypothetical features to report, please select the following at Your convenience:

- a location representing a well,
- a route representing a water course with or without running water,
- and an area representing a dry grass meadow.

Please remember to measure for how long You used the application during the assignment.

Questionnaire

Immediately after completing the Emergency Data Collection Assignment described above, please answer the following questions by filling out the form. Then **save the document** and send Your answers to the author no later than **2013-08-25**.

The answers will be treated anonymously, in such a way that no answer can be traced to any specific individual.

Background:

1. What is today's date (when You are completing this questionnaire)?
2. Do You have experience with GIS in general, through e.g. education or work? Yes No
3. Have You previously participated in emergency/disaster response or recovery operations? Yes No
4. What is the name of Your device?
5. What version of the Android operating system is running on Your device?

The Assignment:

6. Did You read the User Guide, partially or completely? Yes No
 - 6b. If Your answer is "Yes", did You find the User Guide helpful when learning how to use the Application? Yes No
7. Did You complete the assignment successfully? Yes No

7b. If Your answer is "No", why not? (Optional comments)

8. How much time, in minutes and seconds, did You spend using the Application? (Minutes:Seconds) :

The Application:

9. Did You initially find it easy to learn how to use the Application? Yes No
10. After participating in the field trial, do You consider the Application easy to use? Yes No

11. Do You have any suggestions for improving the Application for the purpose of emergency data collection? (Optional comments)

General:

12. Do You have any further comments? (Optional comments)

Thank you very much for participating!

EDCA

Emergency Data Collector for Android™

User Guide



Introduction

This is the User Guide for the mobile application EDCA (the Emergency Data Collector for Android™)*, developed for Google's well-known open source operating system for mobile devices: Android (Android Developers 2013a).

The purpose of the application (the App) is to facilitate simultaneous data collection by many users in an emergency setting. The main features included to achieve this is the utilization of the built-in GPS sensors present in many modern mobile devices running the Android operating system (OS), the use of the Google Maps Android API v2 (Application Programming Interface; Google Developers 2013) for displaying maps and the possibility to store geographic objects with attributes on the device in case internet connectivity is lost. Google Maps also provide the App's base maps.

Server setup

Installation

At present, the App officially only supports one geospatial server software:

- GeoServer (tested on v. 2.2.2, released 2012-11-23, and v. 2.3.4, released 2013-07-28).

Server administrators are referred to GeoServer's website for guidance on how to install this software (GeoServer 2013).

For the purposes of this user guide, the geospatial database keeping the data published by GeoServer is:

- PostGIS 2.0.0, with PostgreSQL 9.1.4 (PostGIS 2013 & PostgreSQL 2013).

A note to administrators: **The only officially supported character set** for databases storing data for the App is **"UTF-8"**.

Creating layers

When creating layers in the geospatial database, there are some things to keep in mind. The geometry types supported are the following (Table 1), as defined in the Simple Features Specification (SFS) by the Open Geospatial Consortium (OGC, 2013):

Table 1: Simple Features Specification geometry types supported by the App.

Point geometries	Line geometries	Polygon geometries
Point	LineString	Polygon
MultiPoint	MultiLineString	MultiPolygon

Non-geometric property data types that are compatible with the App are presented in Table 2, and these properties can be set to allow or not to allow null (empty) values by the server administrator.

* Android is a trademark of Google Inc.

Table 2: Non-geometric property data types supported by the App.

Property	Data Type	Type of Input Allowed
Text	String	Any type of character input. May not allow international characters such as "å", "ı" or "ě".
Number	Integer	Whole numbers, positive or negative.
	Double	Numbers, positive or negative, including decimals.
Date	Date	A date with the format "YYYY-mm-DD".
Time	Timestamp without time zone	A date and time string using the format "YYYY-mm-DD HH:MM:ss".
True/False	Boolean	"true" or "false".

The App draws layers from the geospatial database in the order they are listed, that is, they are drawn alphabetically with the first layer on top. This way, the administrator can determine the layer draw order by e.g. prefixing the layer names with a letter, letting "a_layer" draw on top of "b_layer" and so on.

The Spatial Reference System (SRS) setup required by the App in GeoServer is to, for each layer:

- set the "native" SRS to "EPSG:4326" (WGS 1984),
- set the "declared" SRS to "EPSG:3857", which is the Pseudo Spherical Mercator projection, used by e.g. Google Maps and OpenStreetMap (OSM 2013),
- and finally choose for to GeoServer's SRS handling to "Keep native".

Using styles

Control over the map's appearance is not included in the App, but is rather a combination of Google Maps' pre-set visual style and the layer styles set by the server administrator in GeoServer. GeoServer uses an OGC standard mark-up language called "Styled Layer Descriptors" (SLD; OGC 2013) to define the visual appearance of geographic features, labels etc. The GeoServer User Manual's chapter on styling (GeoServer 2013) provides instructions on how to use this functionality to create visually appealing and practical styles for the layers. These SLD settings can be highly customized to communicate the right information to the viewer, also when multiple layers are displayed at the same time.

Application navigation and use

Figure 1 shows the main menu of the App with buttons that let the user navigate to the basic functional areas (or rather "Activities", as they are called in Android development and as they will be referred to in this User Guide). The icon in the bottom right, always visible in the App, indicates whether or not the App is communicating with the server, such as uploading collected data or asking the server for its layers.

"View Map" takes the user to the map interface, where the user can view the Google Maps with local and server based geographic data overlaid on top. This is also where the data collection is performed, both determining the coordinates and adding attributes of features.

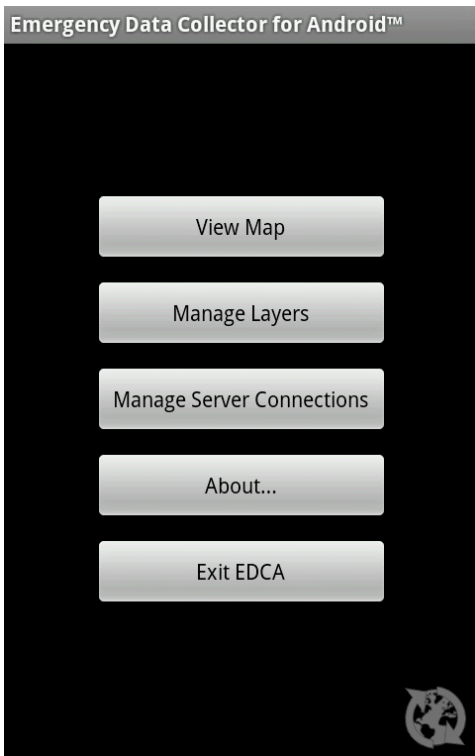


Figure 1: The main menu of EDCA.

"*Manage Layers*" is where locally stored and remotely (from a connected geospatial server) accessible geographic data layers can be interacted with, e.g. by selecting which layers to display on top of the google maps background in the map Activity.

"*Manage Server Connections*" stores connection information regarding geospatial servers and lets the user connect to one, in order to access its map layers.

"*About...*" shows basic application information such as the current software version, which e-mail address to use for contacting the application author and the App's software license.

"*Exit*" closes the App. Note that layers and data that has not been stored locally on the device will be lost upon leaving the App. Layers can be accessed again by reconnecting to the server, but data will be lost permanently.

Manage Server Connections

After pressing the "*Manage Server Connections*" button, the App initially shows the user an empty server list. This list is later populated with the servers added by the user and whose

addresses should be supplied by their respective server administrators (Figure 2).

At the top, the server manager Activity displays the connection that is currently active (or rather the last server to which a successful GetCapabilities request was sent).

Below, there are two buttons. The top one "*Renew Last Connection*" initiates a request to the last contacted server, which updates the App's list of available layers. This button also removes any layers not stored locally on the device from the layer list, including any geographic data that may have been collected for that layer, subsequently adding back the layers now available from the server. Therefore **the user should take care to upload/store any data collected before trying to renew the server connection.**

The second button, "*Add a New Server Connection*", launches the server editor Activity where servers' addresses are entered.

Long-clicking on any listed layer will display a selection of actions. "*Edit*" also launches the server editor but in edit mode, letting the user change the stored server address and "*Delete*" which removes the server from the list.

The server editor Activity, shown in Figure 3, lets the user enter or edit the server address components. There are two different address input modes, selected by checking or unchecking the "*IP Address Mode*" checkbox. In the default input mode the user is required to enter:

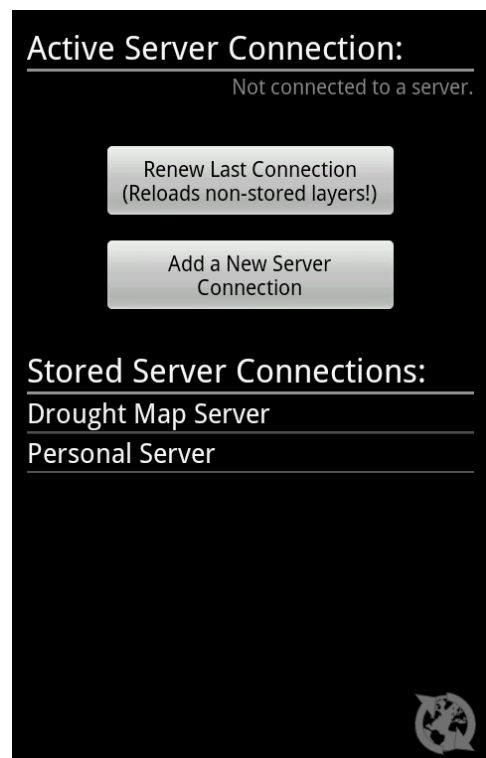


Figure 2: The server manager Activity, where the user can store addresses supplied by the server administrators.

- An arbitrary **name** set by the user to identify the specific server.
- The **full address** to the server, including http/https prefix, hostname/ip and path. The field can not end with a slash, "/".
- The **port** number that the server is listening on.
- The spatial server's layer **workspace** to query for layers.

In the "IP Address Mode" the App requires the same input, except for the full address, which instead is divided into the following parts:

- The server's **IP-address**.
- The **path** on the server where it can receive requests.

If the inputs entered by the user are invalid, the App informs the user about how to format the inputs to ensure that a correct address have been entered.

The server address components come together to form an address like this:

http://[IP address or Host name]:[Port no.]/[Server path]/
[Layer workspace]

Requests are made to the address by appending "wms?" in the case of GetCapabilities or GetMap requests or "wfs?" in the case of DescribeFeatureType or WFS Insert requests.

Below the input fields, the Activity displays the date and time at which this specific server was most recently contacted (i.e. received a successful GetCapabilities request), if applicable, and shows two buttons:

- Save: Saves the server address or enables editing.
- Connect: Connects (or disconnects) to the displayed server, which loads or re-loads the layers available from the server. Also here, the user needs to **keep in mind that any non-stored layers are re-loaded, dropping any geographic information not uploaded or stored locally** on the device.

Manage Layers

The layer management Activity, reached by pressing the "Manage Layers" button in the main menu, shows all the layers available for viewing and data collection, on the server and locally, and lets the user interact and, most importantly, upload the collected data to the server. At the top the currently targeted layer, if any, is shown in red.

Figure 3: The server editor, where the user inputs the spatial server's address supplied by its administrator.

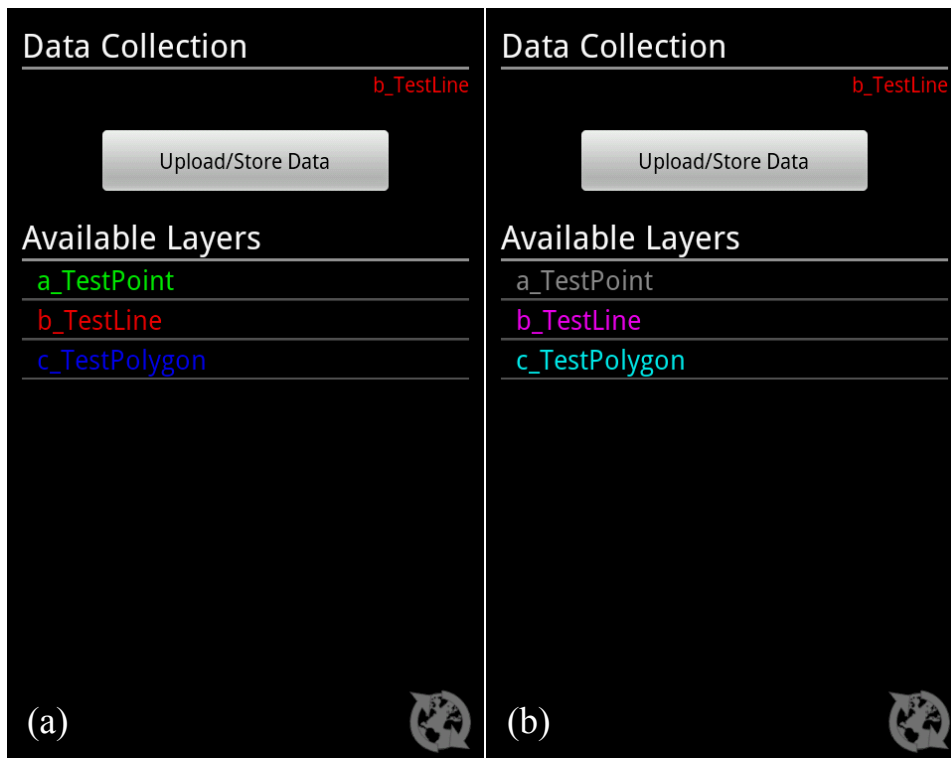


Figure 4: The layer management Activity with two different configurations. On the left (a), the basic states and their respective colours; green for displaying the layer, red for targeting the layer for data collection and blue for storing the layer on the device. On the right (b), the top layer is inactive and the other two layers have a combination of states shown by the combination of the states' colours.

Figure 4 shows the layer management Activity and how the layers can have three different states represented by colour coded layer names. The three states are:

1. Displayed on the map (green)
 - The layers for which displaying is activated will be included in GetMap requests to the server, and are thus overlaid on the map.
2. Targeted for data collection (red)
 - Only one layer can be targeted for data collection at any time and while a layer is targeted any locations or geographic features and attributes added in the map Activity will belong to this layer and any upload will target this layer's corresponding server layer. A non-stored layer can only be targeted if the server can be reached and responds correctly to a DescribeFeatureType request.
3. Stored on the device (blue)
 - This state indicates if the layer is currently stored on the device's external storage, e.g. its SD-card. Stored layers can be targeted for data collection regardless of internet access or if the server is online. Stored data can be uploaded to the server when it becomes available. Collected data is not stored automatically; the user is required to press the "Upload/Store Data" button for the stored data to be updated. Thus, **it is recommended to regularly press the "Upload/Store Data" button during data collection.**

Figure 4 a shows three layers, each layer in a single, separate state. Figure 4 b, on the other hand, shows the same layers in different combinations of these states.

Which state combinations that result in which colours are explained in Table 3. For example, the top layer of Figure 4 a is grey, meaning that the layer is inactive – none of the states are enabled – and the second layer in Figure 4 b is magenta, meaning that the layer is targeted for data collection and stored on the device.

To enable or disable these states for the displayed layers; long click on the layer name. This displays the selection of states, which toggles on or off when clicking "Display", "Collect Data" or "Store on Device".

If the "Store on Device" action is chosen when the layer is already stored, the user can chose whether or not to delete the layer information including collected geographic data and its attributes.

Finally, the "Upload / Store Data" button tries to upload the data to the server. In case of failure the user is asked if the data should instead be stored on the device awaiting a server connection.

Table 3: The possible combinations of states that a layer can be in, and the resulting colour it would be displayed in.

Displayed on the map (green)	Targeted for data collection (red)	Stored on the device (blue)	Resulting colour
No	No	No	Grey
Yes	No	No	Green
No	Yes	No	Red
No	No	Yes	Blue
Yes	Yes	No	Yellow
Yes	No	Yes	Cyan
No	Yes	Yes	Magenta
Yes	Yes	Yes	White

View Map

The map Activity (Figure 5) is where the user can view the map and collect geographic data for upload to the server. The basic map navigation is the same as most Google Maps applications; press and drag on the screen to pan (move) the map. Pressing the map also displays the zoom in (+) and zoom out (-) buttons that increases or decreases the scale the map is displayed in. A button in the upper right corner lets the user toggle between the standard Google Maps layer and satellite images.

There are three ways to add locations in the map Activity and all of them require a target layer to collect data for;

- long-clicking the map will add the clicked position,
- bringing up the options menu and choosing "Add Position" will activate the device's GPS and network location service to find the device's current location,
- and finally the user can, also in the options menu, choose "Enter Coordinates" to manually enter a specific location.

The options menu (at the bottom of the screen in Figure 5) on android devices can be reached by pressing the *Menu* hardware button if the device has one, or the corresponding software button on other devices. Refer to your device manual if you cannot find the *Menu* button. On newer devices the options menu actions should be available in the "Action Bar" at the bottom or top of the screen,

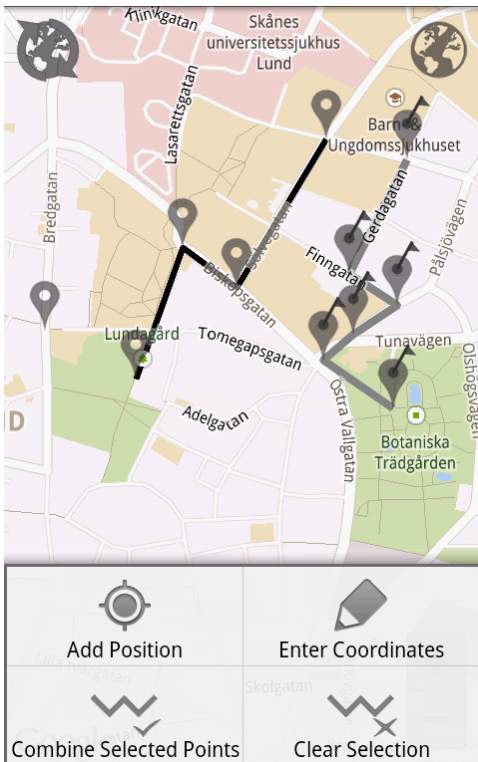


Figure 5: The map Activity, displaying a finalized line feature (black line), a new line being created (grey line) and a location not yet added to a feature.

as a location is found if the layer is of the Point type, or when the options menu action "Combine Selected Points" is chosen.

The attributes that can be added are determined by the layer properties set by the server administrator. Figure 6 shows the attribute editor Activity, used for entering or editing the attributes, and how the App notifies the user which type of input is required. When an attribute is of the time type, the App automatically suggests the current time. Upon invalid inputs, an error notification window is displayed explaining what the input format should be.

Tapping a finalized feature displays the coordinates of the tapped location and the attributes related to that feature (Figure 7). This window also lets the user delete a feature or launch the attribute editor Activity to edit its attributes.

Data collection and reliability

While the accuracy of the data collected is ultimately reliant upon the thoroughness and meticulousness of people collecting it, in this case the App's users, the App provides some measure of input control by supporting different data types and checking that the input is formatted accordingly.

by clicking a "more actions" button (three vertically stacked dots).

If the layer is of a Line or Polygon type, the user needs to combine multiple locations in order to create a feature and add attributes. After adding two locations (or three for polygons) the action "Add to Sequence" (Figure 5) will be available in the options menu. Selecting this action will enable the user to tap a sequence of locations to connect them into a feature.

When the required number of locations have been selected, the option to finalize the feature is be available by choosing the action "Combine Selected Points" in the options menu.

As mentioned, a line requires two locations; a start- and an end location, while a polygon requires three separate locations and that the end location is the same as the start location (requiring four selections total). While selecting locations to combine, tapped locations are connected by grey lines. The selection can be cleared if the user makes a mistake by choosing the options menu action "Clear Selection". After finalizing a line or polygon feature, the lines connecting the locations will be displayed in black colour instead (Figure 5).

Attributes can be added to each feature after it is finalized in the map Activity, which means as soon

Figure 6: The attribute editor Activity, letting the user enter attributes for three layer properties set by the server administrator.

There is currently no support for enumeration, to define specific values to be allowed, but this could be a way to further improve the usefulness of the data.

Regarding the spatial accuracy, when a user clicks the "Add Position" button in the map Activity's options menu, the App displays an accuracy value along with each fix. When locating finishes, the user can use this accuracy to evaluate whether or not to accept the location provided. According to Google's documentation this accuracy is defined as: "if you draw a circle centered at this location's latitude and longitude, and with a radius equal to the accuracy, then there is a 68 % probability that the true location is inside the circle" (Android Developers 2013b, #getAccuracy()).

The most important limitation to the position accuracy is that of the GPS sensors on the mobile devices. Depending on the hardware, the surrounding environment's ability to block signals and the number of and angles to available GPS satellites, the position error can be as good as a few metres for mobile devices using internal GPS sensors (e.g. Zandbergen 2009, Retscher and Hecht 2012). Retscher and Hecht (2012) found mean errors of four recent smartphones to be about 15-20 m outdoors and about 40-65 m indoors.

When trying to find a position in difficult environments, such as indoors, a device may not be able to get a GPS fix at all. In this case the App uses the network location of the device, that is, a location estimated by the mobile phone network, whose accuracy also depends on the distance to the surrounding network masts, to find a location. The network-based location accuracy is often on kilometre level but can also give a position within a hundred metres of the true location.

The App has a limitation in that the internal location handling of the Google Maps Android API (both v1 and v2) reports locations down to microdegrees from the GPS sensors (femtodegrees, $1e-15$ m, when clicking in the map). What this means is that the App has about a decimetre level accuracy at best. This is, however, irrelevant compared to the accuracies of current mobile device GPS technologies.

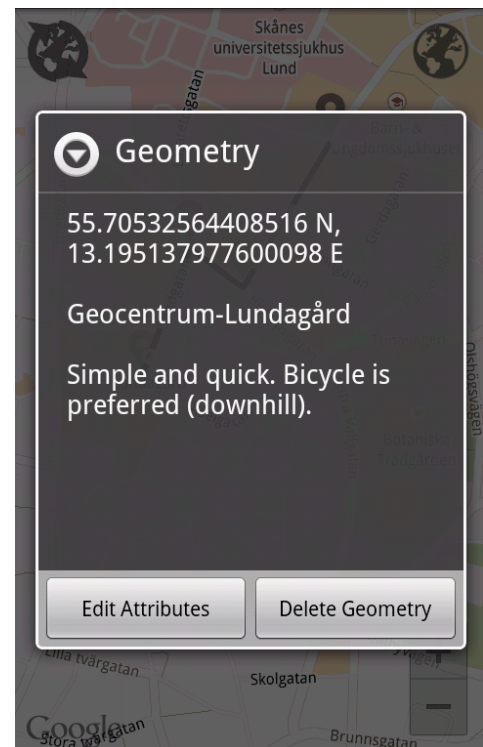


Figure 7: The window displayed when tapping a feature, showing the attributes and letting the user edit them or delete the feature entirely.

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License & Contact Information

EDCA is free software. Users are encouraged to contribute to the Application by commenting, reporting bugs, sharing ideas and even improving the code of the App itself.

License information is displayed within the App by pressing the "About..." button in the main menu, and can be accessed on the App's GitHub webpage, along with the entire source code.

GitHub page: github.com/MattiasSp/EDCA

For any other enquiries, send an a-mail to: edca.contact@gmail.com

Seminar Series

Institutionen för naturgeografi och ekosystemvetenskap, Lunds Universitet.

Studentexamensarbeten (Seminarieuppsatser). Uppsatserna finns tillgängliga på institutionens geobibliotek, Sölvegatan 12, 223 62 LUND. Serien startade 1985. Hela listan och själva uppsatserna är även tillgängliga på LUP student papers (www.nateko.lu.se/masterthesis) och via Geobiblioteket (www.geobib.lu.se).

The student thesis reports are available at the Geo-Library, Department of Physical Geography and Ecosystem Science, University of Lund, Sölvegatan 12, S-223 62 Lund, Sweden. The report series started 1985. The complete list and electronic versions are also electronically available at the LUP student papers (www.nateko.lu.se/masterthesis) and through the Geo-library (www.geobib.lu.se).

- 231 Nitin Chaudhary (2011) Evaluation of RCA & RCA GUESS and estimation of vegetation-climate feedbacks over India for present climate
- 232 Bjarne Munk Lyshede (2012) Diurnal variations in methane flux in a low-arctic fen in Southwest Greenland
- 233 Zhendong Wu (2012) Dissolved methane dynamics in a subarctic peatland
- 234 Lars Johansson (2012) Modelling near ground wind speed in urban environments using high-resolution digital surface models and statistical methods
- 235 Sanna Dufbäck (2012) Lokal dagvattenhantering med grönytefaktorn
- 236 Arash Amiri (2012) Automatic Geospatial Web Service Composition for Developing a Routing System
- 237 Emma Li Johansson (2012) The Melting Himalayas: Examples of Water Harvesting Techniques
- 238 Adelina Osmani (2012) Forests as carbon sinks - A comparison between the boreal forest and the tropical forest
- 239 Uta Klönne (2012) Drought in the Sahel – global and local driving forces and their impact on vegetation in the 20th and 21st century
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- 242 Caroline Jonsson (2012) The relationship between climate change and grazing by herbivores; their impact on the carbon cycle in Arctic environments
- 243 Carolina Emanuelsson and Elna Rasmusson (2012) The effects of soil erosion on nutrient content in smallholding tea lands in Matara district, Sri Lanka
- 244 John Bengtsson and Eric Torkelsson (2012) The Potential Impact of Changing Vegetation on Thawing Permafrost: Effects of manipulated vegetation on summer ground temperatures and soil moisture in Abisko, Sweden
- 245 Linnea Jonsson (2012). Impacts of climate change on Pedunculate oak and Phytophthora activity in north and central Europe
- 246 Ulrika Belsing (2012) Arktis och Antarktis föränderliga havsistäcken
- 247 Anna Lindstein (2012) Riskområden för erosion och näringsläckage i Segeåns avrinningsområde
- 248 Bodil Englund (2012) Klimatanpassningsarbete kring stigande havsnivåer i Kalmar läns kustkommuner

- 249 Alexandra Dicander (2012) GIS-baserad översvämningskartering i Segeåns avrinningsområde
- 250 Johannes Jonsson (2012) Defining phenology events with digital repeat photography
- 251 Joel Lilljebjörn (2012) Flygbildsbaserad skyddszonsinventering vid Segeå
- 252 Camilla Persson (2012) Beräkning av glaciärers massbalans – En metodanalys med fjärranalys och jämviktslinjehöjd över Storglaciären
- 253 Rebecka Nilsson (2012) Torkan i Australien 2002-2010 Analys av möjliga orsaker och effekter
- 254 Ning Zhang (2012) Automated plane detection and extraction from airborne laser scanning data of dense urban areas
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Populärvetenskaplig sammanfattning (Popular Science Summary in Swedish)

Mattias Spångmyr

Ge katastrofhjälp: skicka information med din smartphone!*

Under och efter katastrofer och nödsituationer samlas många olika organisationer för att hjälpa de drabbade. Det kan vara t.ex. polis, brandkår, sjukvård, eller elbolag som måste reparera ledningsnät. Vid större katastrofer kan myndigheter och internationella hjälporganisationer också behöva komma till undsättning. För att dessa organisationer ska kunna hjälpa till på ett effektivt sätt måste de ha tillgång till uppdaterad och korrekt information om krisläget. En stor del av den här informationen är kopplad till en specifik plats; den är *geografisk*.

Idag får organisationer som jobbar med krishantering mycket av sin geografiska information från satelliter och flygbilder, men en del typer av information kan inte ses med satellit. Dessa kan vara t.ex. ledningar som ligger begravda under markytan eller mänskliga skador och behov. Därför behövs också någon form av system som personal och volontärer i fält kan använda för att rapportera till krisledningscentraler på ett effektivt sätt. Många sådana system har historiskt sett varit dyra att skaffa eftersom de krävt avancerade datorprogram och dyr teknisk utrustning till personalen i fält. Eftersom de dessutom många gånger varit svåra att använda har det varit svårt för krishanterings-organisationer att få ihop tillräckligt många personer att hjälpa till.



Mobil-appens logga.

Det här projektet syftade till att utveckla en *mobil-app*, d.v.s. ett program till moderna mobiltelefoner (s.k. *smartphones*). Målet med appen var att alla som äger en smartphone av rätt typ skulle kunna bidra till att samla viktig geografisk information till krisledningscentralen. Genom att låta appen vara en del av ett system som är helt gratis att använda och med öppen källkod, kan även organisationer med små resurser och lite pengar använda den. Tack vare att så många redan äger smartphones som de dessutom redan är vana vid att använda kan det bli lättare att få fler att kunna medverka.

Utvecklingen av appen lyckades och hela systemet är gratis att använda och utgivet – nästan – helt med öppen källkod. Appen testades, men av för få deltagare för att kunna dra några definitiva slutsatser om systemet är lämpligt att använda för krishantering. Dock visade appen och systemet god potential under testerna och att det var möjligt att använda appen för att samla information i en katastrofsituation.

Nyckelord: Geografi, naturgeografi, geomatik, mobil applikation, utveckling, katastrof, kris, nödsituation, insamling av data, GIS, Android, öppen källkod.

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