ASSESSMENT OF A PORTABLE MAPPING TOOL FOR TIME-CRITICAL MANAGEMENT OF DISASTERS

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ABSTRACT:

In the field of disaster response, the following paper presents a hand-held mobile mapping tool that can potentially be used to coordinate field operations, to help navigation of rescue teams and to identify priority areas of high vulnerability. The tool is named "Mobile Geoimager" and is a combination of various sensors aimed to collect coordinates, heading, tilts and medium resolution pictures. The Mobile Geoimager is part of a multi-user framework that incorporates communication technologies between field stations and base station. The tool aims to provide accurate and updated spatial information to field operators and to manage share of field and external information.

Its major interest is to combine a set of technologies using low-cost commercial off-the-shelf hardware. In short, it comprises mobile computer system, GPS, magnetic sensors, digital image sensors and wireless communication. On the software side, the system benefits greatly from free Open-Source software, ranging from databases, operating systems to web mapping technology in order to control the flow of information. It is going to incorporate as much as possible standards and to reduce development efforts by using available software libraries. An accurate integration of already available technologies is expected to enhance information exchange during field operation in disaster response phase.

1. INTRODUCTION

1.1 Motivation

In the field of mobile mapping system, the development of mobile communication systems, along with miniaturization of multi-sensor systems, makes possible the design of portable mapping system. Such mapping systems are especially devoted to coordination of field activities where the main issue is the ability to acquire various type of digital information, store it, distribute it and structure it within a multi-user system.

For this purpose, a tool called "Mobile Geoimager" (MGI) is presented in this paper. The MGI was designed primarily as a portable interface to integrate locally acquired data with remotely transferred information. Such a tool finds a unique opportunity to effectively support rescue operations in case of disaster where time is a critical issue to save lives.

Disasters might be floods, earthquake, tsunami and even major landslide, occurring on large area in countries lacking of accurate organisation to efficiently respond to disaster with rescue teams.

In such circumstances, various international organisations are often involved in rescue operations so as to help local authorities. Effort to coordinated operations between heterogeneous teams is required, which means to establish an efficient share of accurate and up-to-date information.

Initiatives to face such dreaded situations on an international basis are growing among different communities. Recently proposal was made for a Global Disaster Management System (Mahmood et al., 2004) pursuing the recommendations of the 3rd United Nations conference on the exploration and peaceful uses of outer space (UNISPACE III). The concept of the system covers all the four phases of the disaster management cycle, i.e. mitigation, preparedness, response, recovery.

In this paper, support for field operation management in relation to disaster response is explored in detail with regard to the use of a portable mapping system.

1.2 Related work

The work involved here lays partly on the experience gained with mobile mapping systems since its first advent in early 1980s. This was mainly due to the public availability GPS signal.

The current trend is about mobile telecommunication and the development of remote-driven applications supported on hand-held devices (Maguire, 2001; Grejner-Brezinska, 2004). Experiences are also carried out with low-cost systems, where lack of precision is put up with incorporation of external knowledge (Haala, 2003; Zlatanova, 2004). GPS receiver have gain tremendous advances by providing more compact devices and more efficient data collector (Wadhwani, 2001).

In the area of hand-held digital mapping systems, many tools are being developed based on Portable Digital Assistant (PDA) as the primary computing device. The IKE is an interesting bundled system that allows remote measurements of coordinates (http://www.surveylab.co.nz). Mobile mapping softwares like Arcpad from ESRI are commonly used (Huangg et al., 2005). Other PDA-based mapping tools are also used in the field of mobile augmented reality (Newman et al., 2001; Staub et al., 2003; Wagner and Schmalstieg, 2003) and are often used for navigation purposes. Although it lacks portability, POLIFEMO can also be mentioned as it is a precursor of the MGI (Fiani and Pistillo, 2004).

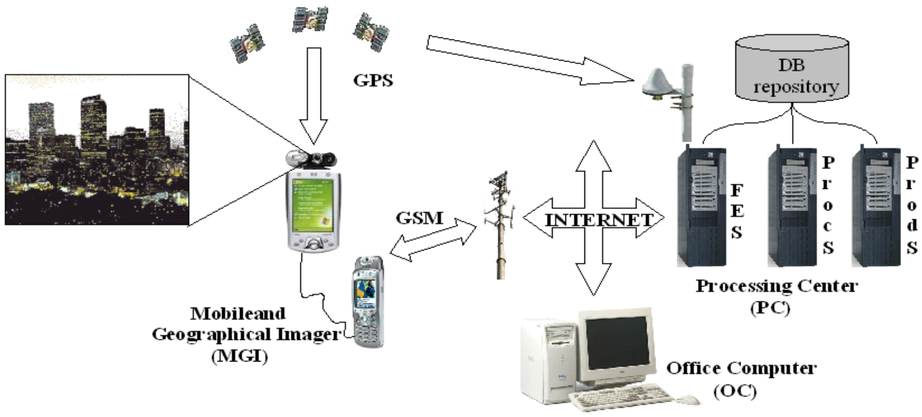

Figure 1. System architecture (Blumer, 2004)

HELIMAP is another example for hand-held multi-sensor system aimed to acquire high precision special data on-board an helicopter (Vallet and Skaloud, 2004). It has the advantage of a short planning phase and a quick product delivery.

Our system also relies on the implementation of an integrated communication network (ICN) where various types of georeferenced data can be remotely shared in real-time. The basis for such a system was defined under the concept of "Telephotogrammetry" (Blumer, 2004). A local area network (LAN) is build to allow interconnection the various users of the system sharing information and processes.

The delivery of geographical information through the LAN, involves thematic data, positions, georeferenced images, and even elaborated maps. Web Mapping (WM) technology tremendously helps us for such a task. WM is already used in the field of disaster response (http://mapsherpa.com/tsunami/, Shaw, 2003). It extends Geographical Information System (GIS) capabilities by transferring dynamically through the web up-to-date geographical information.

2. TOOL AND ARCHITECTURE

The detailed description of the MGI and its integration in a communication network is given in the following chapter.

2.1 General architecture

The MGI relies first on an integrated communication network (ICN) used to exchange information (digital data) between field operators, handling the MGI, and a centralised Processing Centre (Figure 1). The overall system uses wireless communication technology in a client-server environment.

Two domains of functionality are distinguished. On the field, we have the mobile stations grouping several MGIs that collect information and communicate with one remote base station. The other domain is the management headquarters where the base station is located. It is composed of a Processing Centre (PC) that has the task to centralize various kinds of data, produce maps on-demand and synchronize data with external databases. Additional interaction is established with Office Computer (OC) linked to the network.

The system is essentially based on low cost technologies using commercial off-the-shelf (COTS) hardware for computers, servers, portable devices and network infrastructure. It also depends primarily on open-source software, libraries and operational systems (PHP, Mapserver, Postgresq, lLinux).

2.2 Group of users

In the context of the ICN, different groups of users are defined, each assigned to a specific task as described in Table 1. They are the main actors of the system which cannot be efficient without human intervention.

Group of users	**Tasks**
Field operators	Part of a rescue team, handle the MGI, provide field information, analyse site conditions
PC managers	Manage database system, maintain wireless network and GPS corrections server
OC operators	Provide additional cartographic products from internal or external sources and assess acquired geospatial information
Public	Provide external knowledge to the system when required or information is lacking

Table 1. Group of users and tasks

Brand	Ipaq hx4700
CPU	Intel PXA270 624 MHz
ROM	128 MB
RAM	64 MB
OS	Pocket PC 2003SE
Storage	SD card, Compact Flash
Screen size	480x640 pixels
Network	Bluetooth, infrared, USB WLAN 802.11b
Touch-screen	yes

Table 2. Characteristics of the computing device

2.3 Mobile Geoimager (MGI)

The MGI is a hand-held device based on Personal Digital Assistant (PDA) for the computing device. Within the communication network, it plays the role of a thin client that incorporates the following functions.

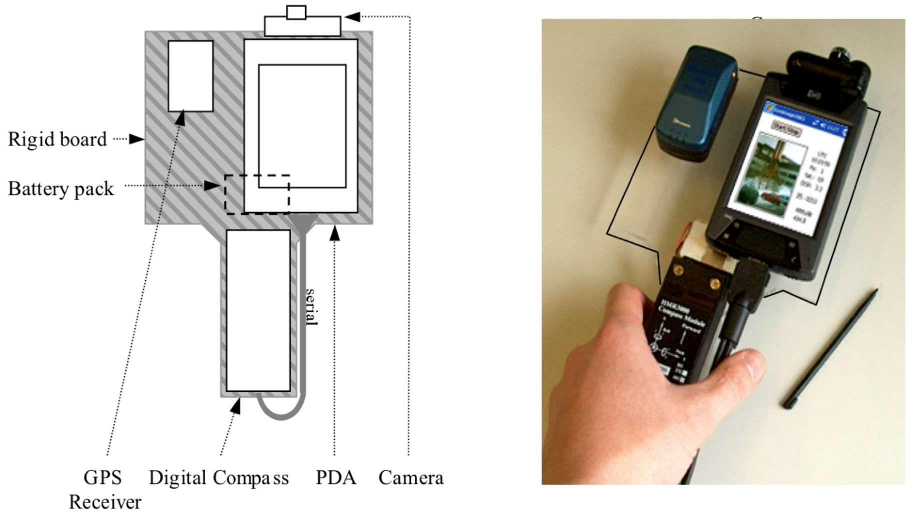

Figure 2. Scheme and snapshop of the MGI prototype

1. Image capture
2. Coordinate measurement
3. Heading and Tilts measurement
4. Temporary data storage
5. Wireless Network connection
6. Screen display
7. On-screen digitizing

It is expected to be light-weighted, small and carried with one hand. The Figure 2 illustrates a full-featured prototype of the tool. The main characteristics of the computing device are detailed in Table 2 and additional modules in Table 3. A selection of hardware brands is also proposed.

The prototype helps to test the tools for each of its functionalities together. Powering the prototype is easy as each device has its own battery. The only problem was to find the correct place for the magnetic sensor in order to reduce magnetic interference coming from the other devices, especially the PDA. A proper calibration has to be made afterwards when all the devices are set together.

GPS Bluetooth modules:	
Brands:	Holux GR230
	Fortuna Clip-on
	GlobalSat BT-308
Differential	WAAS enabled
Theoretical precision:	5-10m non-DGPS
Camera Module:	
Brand:	Lifeview CF Flycam 1.3M
Sensor:	CMOS
Color:	RGB
Resolution:	1024x1280 pixels
Digital compass and inclinometer:	
Brand:	Honeywell HMR3000
Type:	3-axis magnetometer
	2 tilt sensors
Theoretical precision:	Heading: 0.5 degrees
	Tilts: 0.2 degrees

Table 3. Module specifications

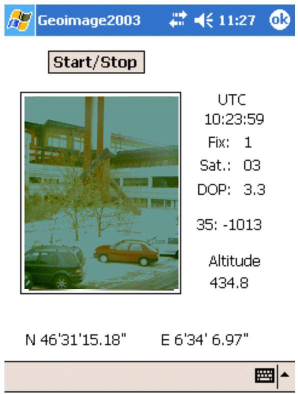

Figure 3. Snapshot of the user interface for simultaneous GPS and image acquisitions

To synchronize the various functionalities of the MGI, light software development is necessary. PocketPC 2003 operating system allow an easy development of applications using the free C++ Embedded Software Development Kit (Embedded Visual C++, EVC++) distributed by Microsoft. The Figure 3 illustrates a user interface where simultaneous acquisition of imageries and GPS coordinates is made possible. A simple "click" allows to store image with incorporation of spatial coordinates, heading and tilt values, time and numerous additional parameters.

Initial tests using the conventional GPS Bluetooth modules show that an accuracy of less that 4 meters can be achieved using the raw acquisitions without additional corrections. WAAS corrections or differential GPS measurements might increase even better measurement of positioning coordinates, which is essential for the reliability of the system. With differential correction using two bluetooth modules 50% of the measurements are lower than 2 meters.

2.4 Processing Centre (PC)

The PC comprises of three units used in a client-server organisation (Figure 1). One is devoted to interact with the MGI or the OC and is called the front-end server (FES). It is used to facilitate the exchange of information. It is made of a web server enhanced with PHP technology.

The second one, the processing server (ProcS), will perform high intensive processing tasks of data and is built on powerful hardware components. It will in particular be used to generate 2D and 3D cartographic products according to data availability and user's wish. 2D cartography will be generated using Mapserver Web Mapping Tool, whereas 3D cartography will be managed using X3D standards, and OpenGL rendering tool.

The third one, the GPS correction server (CorrS), will perform GPS coordinated acquisition, correction computation and then transfer correction parameters to MGIs.

All of the units are linked to a single database DBrep aiming to structure and maintain all field data. Additional link to external database can also be available.

2.5 Wireless connection

The communication between the PC and the MGIs is established using wireless communication systems. Different technologies exist and are likely to be used. Details are given in the following table:

				WIFI	
Mode	**GSM**	**GPRS**	**UMTS**	**802.11b**	**802.11g**
Data rate	9.6 kb/s	<114kb/s	2 Mb/s	11 Mb/s	54 Mb/s
1 MB	13 min	1.2 min	4 sec	0.73 sec	0.15 sec
Operators	Yes	Yes	Yes	No	No

Table 4. Wireless communication technologies

The three first technologies are digital mobile telephony systems but can also be used to exchange data. Their advantage is their wide spatial coverage. The two last technologies refer to WIFI (Wireless fidelity) which is a standard for wireless local area network. It has the advantage to be deployed easily and quickly according to needs, but has drawbacks to lack of extended coverage.

An additional wireless communication system is being developed. The Worldwide Interoperability for Microwave Access (WIMAX) is expected to deliver 109 Mbits of data around a 50 kilometers radius area. Operators might not be necessary as long as wireless users are kept few for a specific operation.

2.6 Spatial Data Management

The management of data and its nature is an important aspect to the system. Spatial information is provided from two sources, essentially from field activities or from remote data services.

The first source of information depicts the actual field situation and is a key-component for operation description and coordination. The nature of the information can be either thematic or image-based. In all cases the information is georeferenced.

Concerning the second source of information, it is used to inform field operators by providing them with imageries or maps covering their work area. This can be real-time information about global field operations, past information about predisaster state or even interpreted information about the disaster area.

The different ways to use information is described more in detail in the next chapter.

2.7 Organisation

The system architecture described here defines a way to exchange geospatial information during a crisis situation. Its goal is to support conventional disaster coordination activities and to distributed accurate spatial data to a wide range of users. By such a mean, a more efficient synchronisation can be established between management work and field work activities. It will ultimately largely facilitate decision making, where having accurate and up-to-date information is crucial, and improve effectiveness of communication during field operation.

The information should be freely available to anyone interested to know about the activities. Experience or advice of external users should be taken into account and integrated in the database. So it is also planned to use a web interface, so that the public may query and visualise the information and ultimately make comment. Such interface is called "disaster response blog" with reference the the well-know internet blog movement.

3. IMPLEMENTATION

The following chapter will develop more in detail several use cases of the proposed system. The particular type of information and its potential use are described with regards to disaster response activities.

3.1 Real time coordination

The Integrated Communication Network (INC) established between the different groups of users allows a real-time share of information and a better coordination of the field activities. For example it becomes possible to map the various MGIs on the field and associate additional information concerning their specific activities.

3.2 Disaster area navigation

To help deploy rescue team within the disaster area, map of the area can be provided directly to the MGI in 2D, or even in 3D format, according to data availability. Maps are then automatically oriented according to the viewer direction, i.e. the orientation of the MGI.

In the case of 2D format, maps may be available under the form of topographic maps or Earth Observation (EO) products (digital aerial photos, satellites imageries) acquired before or during the disaster. Such information can be collected before the disaster as a disaster preparedness effort or during the disaster through various quick acquisition of EO data. At this point, we can mention the International Charter "Space and Major Disasters" which goal is to provide up-to-date EO products through a unified and rapid system of space data acquisition and delivery (Bessis, 2004).

Concerning 3D maps, with the MGI it becomes possible to overlay 3D information (for example 3D city models) with picture shots acquired by the MGI. This would give a better knowledge of the site conditions in relation with the existing disaster area. In this matter, development of 3D GIS is likely to be of high relevance.

3.3 Identification of vulnerable areas

Based on the functionalities described in the previous section, the MGI might be used to identify areas of high vulnerability. Such areas, where a higher amount of victims can be expected (especially urbanised areas), have to be located quickly in order to prioritize rescue activities.

This functionality requires availability of data, especially EO high resolution imageries, acquired before the disaster, that are best suited to describe the land use (roads, buildings, parks) and the human activities (residential, commercial, industrial).

3.4 Localization of area of interest

Another use of the system is to facilitate the localization of particular features that are not visible or recognisable due to the impact of the disaster. For example, using 2D or 3D mapping tool, navigation route can be displayed on the MGI to localize risky infrastructures that are likely to provoke secondary disasters (explosion of unstable fuel containers, collapse of a bridge, unstable high buildings).

So there is a way to combined on-site images with information acquired before the disaster in order to better understand what has happened and what might be the danger during rescue operations.

3.5 Damage mapping

Finally, the last functionalities proposed is to map damages on the field using available EO product. Such activity is, indeed, tremendously facilitated by the combination of field observations and recent imageries covering the area.

Damage maps are an important source of information when we want to describe the effect of the disaster. It is used later on for the study of historical events.

4. CONCLUSION

We have explored in this paper the use of a hand-held mobile mapping tool that is managed within an Integrated Communication Network. The tool allows to collect field information, usually images, and combined it with remotely available data characterising the area under investigation. The network is used as a mean to share information between field operators, office team and even the public. Both establish a strong synergy in order to have a shared knowledge of the rescue activities.

The tool is especially useful when dealing with time-critical information. During crisis situation after natural disasters, it is indeed very important to help rescue teams to navigate in the field. They want to locate survivors quickly without putting in danger their own life.

For such reason the tool and the network described here is of high importance and should be taken into consideration by organisation involved in rescue operation during disasters. It is less of a high financial investment but more about a accurate use of existing technologies to improve the efficiency of disaster rescue activities.

5. ACRONYMS

COTS: Commercial Off The Shelf
EVC: Embedded Visual C
GPRS: General Packet Radio System
GPS: Global Positioning System
GSM: Global System for Mobile telecommunication
UMTS: Universal Mobile Telecommunication System
WIFI: Wireless Fidelity
WIMAX: Worldwide Interoperability for Microwave Access
X3D: eXtended 3D

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