A short survey of existing emergency management tools for information collection, communication, and decision support

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***Abstract*[†]— Over the recent years, international public experiences increased occurrence of natural and man-made disasters involving large human casualties and fatalities, displacing affected population, and bringing immense material loss. To cope with such devastating and highly unpredictable events, disaster managers and first responders participating in the crisis aftermath, need all the existing technological help to be able to provide timely and accurate response, better coordination, and overall risk prevention and mitigation. In this paper we provide an overview of current state of the art commercial, open-source, and research emergency management tools aiming for recovery phase: disaster in-situ data collection, communication and DSS (decision support system) tools. An overview of general requirements for such critical tools is given as well and some integration challenges identified.**

I. INTRODUCTION

We are all witnesses of the rise of the number of natural disasters, even in the regions that were previously unfamiliar to it. A recent example comes from the Italian island Sardinia, that was struck by the unexpected cyclone Cleopatra taking 18 lives and injuring much more [1]. Natural disasters (earthquakes, floods, tsunamis, landslides, avalanches, etc.) along with disasters produced by humans (oil and hazardous chemical spills, explosions, train derailments, etc.) produce over the year a large number of human casualties and material loss that can be measured in billions of dollars [2]. Furthermore, after the disaster strikes the population from endangered area becomes harshly impacted and often displaced and lost in the surrounding area with little or no basic life necessities.

Immediate crisis aftermath (rescue and respond phase) [3] presents first responders (FRs) with time-consuming and extreme physical and mental challenges: efficient assessment of the situation and the potential risks on the terrain before requiring more help, search and rescue (S&R) of trapped and injured victims, provision of the initial medical attention and triage to the most endangered, coordination of the evacuation of the affected people to emergency shelters, assessment of the needs for relief support goods, assembly of support goods and dispatch to the concerned zone.

Disaster scene can involve several different groups of actors ranging from: local and international FR groups (military, fireman, policeman, medics, search and rescue teams, etc.). Furthermore, FRs operate in harsh environmental conditions (debris, fire, floods, toxic gases, etc.) along with ruptures in communication and power infrastructure.

Having in mind everything previously stated, it is clear that emergency response actors require all the necessary technological help i.e. a system that will provide a holistic overview of the situation with potential risk assessment, continuously updated with the most recent and relevant inputs from the field. Such system should also provide a coordination and tracking of involved people and goods during the entire rescue and recovery phase. Finally, the system should provide an efficient mode for voice and data communication, being able to provide independent operation regardless of remaining power and communication infrastructure on the emergency site. A visionary glimpse of future version of such system can be appreciated in a video prepared by the USA Department of the Homeland Security [5].

In this paper, we start by introducing the general emergency management properties and end-user requirements. We continue by providing an overview of state of the art commercial, open-source, and research tools and prototypes for emergency management aiming for the recovery phase. We have focused on solutions providing answers along the entire information flow from a disaster site to a disaster-safe segment: from the information collection at the disaster site, through communication domain, up to the decision support system, serving emergency managers and decision makers. For each of these segments, we provide a short overview of the most prominent and relevant tools with their features and shortcomings.

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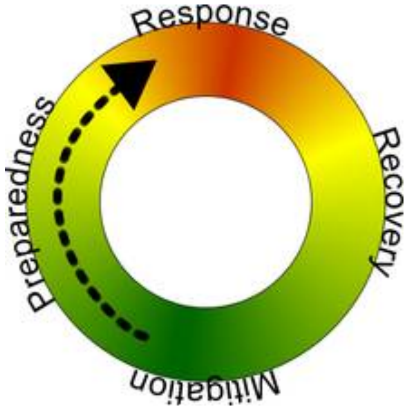

Figure 1 The disaster risk management cycle overview: preparedness, response, recovery, and mitigation

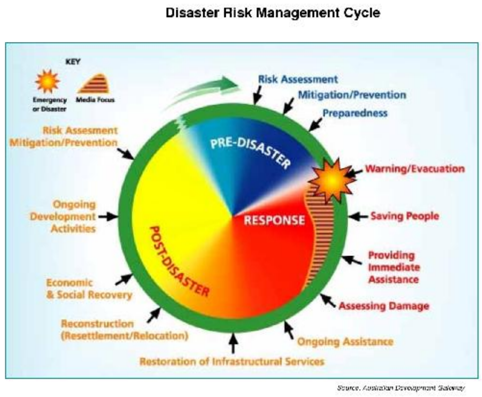

Figure 2 The disaster risk management cycle example with specific actions listed

II. EMERGENCY MANAGEMENT PROPERTIES & GENERAL END-USER REQUIREMENTS

Emergency management is composed of four phases: preparedness, response, recovery, and mitigation (cf. Figure 1). Preparedness includes a detailed plan on how to respond to a specific disaster, with definition of exact lines of command and control and distribution of activities between responsible agencies. Response phase executes all envisioned plans with potential improvisations, due to additional, unforeseen complexity of disaster at hand. The goal of recovery phase is to provide the assistance in the clearing up from the disaster and to help the affected people to regain their normal ways of life. Mitigation insists on putting additional plans in place to prevent re-occurrence of disaster if possible or at least to minimize damage cased by the next occurrences. In this paper, we will concentrate on existing technological solutions aiming at the response phase (cf. **Figure 2**).

Most natural and manmade disasters have specific nature: they differ in type (earthquakes, floods, tsunamis, landslides, avalanches, oil and hazardous chemical spills, explosions, train derailments, etc.), affected area (from city blocks, entire cities, regions, up to entire countries [cite Pakistan]), number of affected people (from dozen people affected by Sardinia cyclone, to millions in Tahiti earthquake), economic loss, involved FRs groups, etc.

Nevertheless, a list of general requirements for EM tools for response phase is available [6]:

- *Holistic overview of the situation*: decision makers coordinating the response should be provided with a clean visual overview (maps and rich data) with possibility to explore further details. Abundance of information collected from the field (situation awareness reports, FR risk reports, images, videos, or crowd-sourced inputs) should be filtered, synthesized, and presented according to their quality, relevance, and timeliness.
- *Efficient organization and coordination*: decision makers should be provided with a visual way to track advancement of involved personnel and transported goods. Clustering and quantification of response goods and personnel should be provided.
- *Compatibility*: all emerging response tools should ensure compatibility with previously used EM tools whenever possible.
- *Near zero configuration and training*: provided tools should come pre-configured and ready to be deployed straight from the box (plug & play principle). Additionally, EM tools should be easy to use with no or little prior training. FRs time should be maximized to save lives.
- *Secured and independent two-way communication*: in the time of emergency majority of public and private power sources and transmission lines as well as communication infrastructure is susceptible to be destroyed or if remain standing to be overly congested [4]. Thus, an independent means of communication should be provided, offering two-way audio and favorably video calls.

III. RELATED WORK

In the following section, we summarize the current state of the art solutions for the response phase, regarding three main aspects: in-situ data collection and management, disaster communication, and decision support and coordination systems.

A. Field (in-situ) data collection and management tools

Having an eye on the exact situation in the field has a precious value for emergency managers. Up to date information provides a basis for timely and accurate response, better coordination and overall risk prevention and mitigation.

Field information can come in different forms: textual (e.g. situation and risk assessment reports, list of people and equipment in the field, lists of missing, injured, and dead people, etc.), audio-visual (images and photos, videos, earth observation satellite imagery, live and recorded voice, etc.), and specific (environmental sensor readings, weather data, location and timing information on people and objects).

Field information can be provided by trained specialists or crowd-sourced by population in the affected zone. Abundant information from the field could be harvested through various platforms: web-based, commodity devices (PC, smartphones, tablets), or specialized hardware (e.g. UAV, weather balloons, EO satellites).

1) Web-based tools

Big technology player Google publicized the use of web-tools in Crisis Response. Such solutions are freely available to international public, often support multiple languages by virtue of a large support community, and are convenient for people with little or even no previous technical knowledge (a simple internet browsing competence could suffice).

We list some of the most prominent solutions:

- **Google Crisis Response** [7]: Technology giant has applied its widely accepted tools and created specific tools for the crisis sector: *Public Alerts*: a renowned platform for collection of latest critical information about weather alerts and approaching natural disasters, before they cause a damage. Platform allows creation of services through combination of maps with overlays of relevant announcements. Services are seamlessly integrated with Google search, maps, and notifications. *Person finder*: a simple and effective open platform, allowing individuals and organizations to provide information and conversely to look for missing persons. *Crisis map*: provides a mashup tool to collect, contribute, combine, and explore critical disaster-related geographic data, without any specialized software.
- **Virtual OSOCC**: an international information exchange and coordination portal for early phase of major disasters. Created by GDACS cooperation framework between the United Nations and the European Commission, it is intended for exclusive use by disaster managers worldwide. Virtual OSOCC organizes information by event and handles several data types: field data (geo-tagged reports and photos/videos), in-situ sensor measurements, GIS, model output data, priority areas, baseline data, and satellite image derived data (e.g. flood extent, earthquake damage assessment). Virtual OSOCC incorporates maps produced worldwide by UNITAR/UNOSAT network of collaborators based on collected satellite and GIS data from many organizations. Virtual OSOCC handles and analyses mass and social media specifically related to worldwide disaster events.

2) Smarthone-based tools

High market adoption, performance boost, versatility, and portability of smart mobile devices made its way to people's everyday lives including the emergency situations. We want to highlight some of the most prominent emergency applications optimized for mobile devices (prevalently Android based):

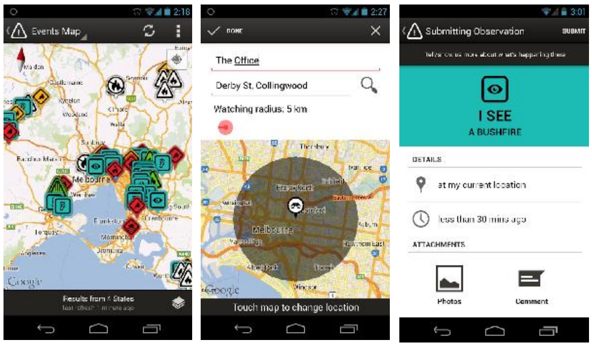

Figure 3 Emergency AUS: a simple and intuitive interface for emergency updates and reporting

- **Emergency AUS/ FireReady**: issued by Australian Government to provide timely and relevant emergency information to affected population. Users (professionals and ordinary people) can provide relevant information about ongoing emergency, through an intuitive step-by-step interface where geo-tagged images and text can be attached at the end (cf. **Figure 3**). Users can as well follow the status and additional information about various types of emergencies (e.g. fire, storm, earthquake, landslide) on a map, or through a subscription system. Application offers a community support mode where users can request or offer relief support goods and accommodation. Further promotion and international support is needed (for the moment, Australia only).
- **UN-ASIGN**: an application resulting from EU FP7 project Geo-pictures allows actors of an emergency (both trained personnel and affected population) to provide geo-tagged input (photos and reports). During the Thailand floods, 2009, UN-ASIGN allowed EM decision makers to fuse all the inputs from the field in order to localize and visualize on a map the area covered by water and finally to gain better overall situation awareness. Currently, UN-ASIGN is missing structured pre-made reports, guiding the FRs through the process.
- **HelpBridge**: an application aiming to facilitate the collection and request of disaster relief, promoted by Microsoft and several relief organizations (American Red Cross, Care, CRS). Benefactors can directly provide financial and material donations, along with their time to volunteer in case of a crisis. Application allows affected population to connect with some of the world’s leading disaster relief organizations in order to request help and assistance. HelpBridge needs further promotion and international support.

Figure 4 sensFly drone for earth mapping

3) UAV-based tools

Recent development and commercialization of the small UAV (Unmanned Aerial Vehicles) asserts them as a reliable tool for emergency response. UAVs equipped with various imagery sensors offer a unique visual input from the birds-eye perspective (cf. **Figure 4**). UAVs can extend their operation even to the hazardous and inaccessible zones (e.g. areas affected by radiation and toxic chemicals, steep mountain slopes, or swamps). UAV (both quadcopter and gliding planes) demonstrate extraordinary agility and stability even in presence of disturbing factors (strong winds or propeller / motor failure) [13]

We can point out some notable use-cases of UAV in emergency scenarios:

- **Earth surface mapping and modeling**: Swiss based company *senseFly* offers a complete solution for accurate mapping used for environmental management, mining, construction industry, and emergency management. Autonomous drone (cf. **Figure 4**) (1m wingspan with 45 minutes flight) coupled with photogrammetry software allows mapping of an area up to 10 km^2 with up to 3cm precision. *senseFly* successfully completed several missions at Tahiti providing an estimation of number of new residents along with garbage concentration, as well an assessment of the water drainage in several neighborhoods of Port de Prince.
- **Indoor mapping**: members of GRASP Laboratory at Penn Engineering create and develop autonomous quadcopters enabled to explore and map unknown and complex 3D indoor environments [11]. The quadcopters equipped with a range of sensors (inertial, cameras, a laser range scanner, an altimeter and a GPS) allow precise mapping. Quadcopters have a large potential in urban search and rescue and first response missions, especially where hazardous materials are involved [12].
- **Combined S&R in inaccessible terrain:** A specialized FP7 SHERPA project aims at building smart ground and aerial robots that will collaborate with Alpine rescue teams. Ground robots will serve to probe the unstable terrain before rescuers engage in potentially dangerous zone. Aerial units will continuously scan the monitored area after an avalanche looking for survivors, while Alpine rescue provides help to previously found victims. First working prototypes are expected in 2015.

Figure 5 CISCO NERV vehicle - a complete telecommunication emergency recovery solution

B. Disaster site Communication

Efficient and reliable disaster site communication is *conditio sine qua non* link in the chain of extracting the field input data and delivering it to the outside world (relevant emergency decision makers and journalist).

Recent study from American Homeland Security [4] indicates that during disasters, communication networks become highly compromised. On one hand, disasters bring destruction to both power (primary and backup) and communication infrastructure, limiting its use and reach. On the other hand, crisis situation produces an increased demand of communication leading to network congestion and failure. As a result, communication outage can last even up to couple of weeks, depending on the severity of a disaster, where the first 24-36h after the disaster are the most critical for the response and relief.

Currently, there are several solutions that can help bridge the communication gap between the imminent disaster site and outside world:

- **CISCO NERV**: a specialized CISCO truck vehicle (cf. **Figure 5**) provides an integral and robust telecommunication solution for emergency scenario. NERV is entirely independent from remaining power and communication infrastructure at the disaster site. NERV come equipped with a complete communication solution (UHF/VHF radio, 2G/3G mobile base station, WiFi) with a high-bandwidth satellite backhaul. NERV comes with built in support for VoIP and video calls, and data exchange. A dedicated videoconference room is situated at the back of the truck. CISCO Tactical Ops have already provided a rapid deployment and assistance in case of 30 major emergencies around the globe.

Figure 6 Emergency.lu rapid deployable kit with an inflatable satellite dish

- **Emergency.lu**: offers a complete emergency communication service: a pre-configured rapid deployment kit (cf. **Figure 6**) featuring an inflatable satellite dish with all necessary communication gear, a pre-booked satellite capacity and a free standby airborne transportation, available after 2h following the demand. Once deployed, it offers a rich set of services (VoIP, IM, tracking & tracing of people and equipment, map assessment, asset management, situational reports). Emergency.lu is supported by UN and financed by the government of Luxemburg.
- FP6 WISECOM project: provided through live trials an integrated communication infrastructure - a standalone, independent, portable communication unit combining advantages of different technologies ranging from TETRA, WiFi to GSM and 3G with both Inmarsat BGAN and DVB-RCS satellite backhauling systems. Location based services were incorporated in the solution to offer tracking and triage of patients in the field.

Larger network coverage, beyond the satellite backhauled equipment described previously, can be obtained through wireless mesh solutions. Generally, a deployed wireless mesh network becomes more robust by adding more nodes. We can point out some of the following prominent solutions:

- **Rajant**: a reliable provider of wireless multi-frequency mesh solutions for challenging military, underground mining, railway, and emergency use. Battery powered, rugged *BreadCrumb* nodes extend coverage even in harsh environment and inaccessible areas. Several wireless interfaces provide higher resilience to interference and jamming. Rajant solutions allow VoIP and video communication, along with data and remote monitoring information. Provided solution remains functional even when network becomes fragmented - communication continues locally, awaiting connection to the backbone of the network.
- **Mesh Dynamic**: another proven provider of robust wireless mesh solution, specialized for challenging use in emergencies. A robust multi-frequency solution is suited for hastily formed networks requiring easy installation, low set up efforts and high data rates over many wireless hops. Mesh Dynamic provides connectivity and video streaming even in a case of fast moving vehicles (up to 90km/h).
- **Serval project**: an open source initiative from University of Auckland for anytime, anywhere, secure communication outside mobile tower coverage. Key idea is in using available smartphones with in-built WiFi capability. Smartphones with Serval app allow building impromptu networks in areas with no or low mobile coverage (e.g. 75% of Australia lacks mobile coverage) for cost-effective solution (no mobile subscription required). Serval supports VoIP calls, IM and file exchange with 256bit ECC encryption. Wireless mesh network coverage can be additionally increased up to 10 to 100 times compared to standard WiFi coverage with additional equipment called MeshExtenders: a battery powered mesh-enabled devices mounted on a 6m pole. Serval project develops and evolves with a support of open-source community.

C. Decision Support System (DSS)

Final step in EM tool chain laying atop of in field data input and emergency communication is the EM DSS. Similar tools, capable to absorb a potentially large amount of relevant, up-to-date and heterogeneous data, to filter them by relevance, further extract and recombine in order to build a common overall holistic situational awareness picture with rich underlying details.

DSS platform should provide decision makers with a support tool for more efficient reasoning based on up-to-date information. We can select some prominent examples:

- **Ushahidi** [9]: a non-profit tech company that develops free and open source software for information collection, visualization and interactive mapping. *Ushahidi platform* was initially developed to map reports of violence in Kenya at the beginning of 2008. Eventually Ushahidi platform found widespread use in crisis information mapping after the Haiti earthquake [10]. *Ushahidi* and its web-version *Crowdmap* offer seamless collection of crowdsourced information (optionally geo-localized) from multiple sources (SMS, email, Twitter and the web) and further presentation on interactive map. *SwiftRiver* platform complements Ushahidi by providing open-source tools for filtering and mining of real-time information.

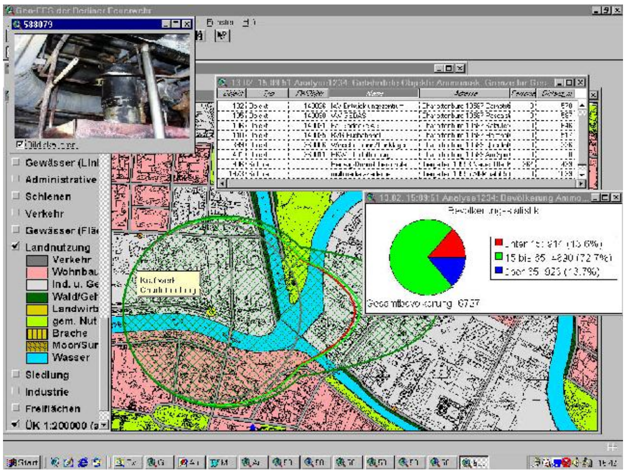

Figure 7 GeoFES: a powerful and intuitive DSS tool for emergency managers

- **GeoFES**: an ESRI ArcGIS-based software, providing support for decision makers at fire brigades and disaster management services. GeoFES is an efficient EM DSS tool in the event of wide range of natural and man-made disasters (storms, floods, fires, nuclear, biological and chemical (NBC) incidents, epidemics) (cf. **Figure 7**). It can also be used for preventive planning and training purposes. GeoFES focuses on the following main topics: a. Fast identification and preview of the emergency location in the interactive map. b. Synthetic and holistic overview of all current risks - enable better preparation and decision-making. c. Simulation, modeling and estimation of hazard substance propagation in the air and water to guide and support S&R and evacuation actions. d. Evaluation of the endangered zones - population and buildings statistics. e. Operational management of emergency services f. Adaptation of digital content for fire fighters without digital equipment.
- **Sahana** [8]: an open source foundation providing software and services that help solve concrete problems related to disaster response coordination. Sahana provides tools for management of missing and found person, tracking of organizations and programs responding to the disaster, providing transparency in the response effort, project tracking by enabling relevant sharing of information across independent organizations. Additionally, Sahana provides a management tool for hospital triage.
- **EmerGeo Fusionpoint**: a powerful web-based Crisis Information Management System (CIMS) with DSS integration allowing secure access from anywhere. Fusionpoint connects to customer's existing systems to merge and publish data. It combines logging and reporting, real-time data fusion, OpenGIS and ESRI mapping and web portal technology to bring together data and process from multiple emergency and non-emergency applications. Users can customize their web dashboard to extract only the most relevant and critical information for decision making. EmerGeo Fusionpoint Integrates with: alert notification systems, Dispatch Systems, GIS Mapping Systems, CCTV, Hazard Models and Simulation tools, Live Data Feeds (weather, news, GeoRSS.

IV. CONCLUSIONS

Increased occurrence of natural and man-made disasters has lead EM managers, decision makers, and responders to reach for any available help allowing them to work more efficiently, in a coordinated way, helping them to mitigate and relieve devastating effects of disasters.

In this short survey we have provided an overview of state of the art the technology solutions for emergency management aiming for the recovery phase. We have selected representative tools for information collection at the disaster site, disaster communication equipment, and decision support systems.

We believe that our survey paper can be beneficial to both EM personnel and technology developers and researchers seeking a concise overview of main EM technology tools.

REFERENCES

[1] Sardinia hit by deadly Cyclone Cleopatra and floods, BBC Europe, 19.11.2013, http://www.bbc.co.uk/news/world-europe-24996292

[2] UN GLOBAL ENVIRONMENT OUTLOOK, Socio-economic effects, http://www.unep.org/geo/geo3/english/448.htm

[3] Coppola Damon P. (2007): Introduction to International Disaster Management. Oxford: Butterworth-Heinemann.

[4] Gerard O'Reilly, Ahmad Jrad, Ramesh Nagarajan and Theresa Brown, Stephen Conrad, "Critical Infrastructure Analysis of Telecom for Natural Disasters", Telecommunications Network Strategy and Planning Symposium, 2006

[5] Precision Information - Vision Video, Department of the Homeland Security, USA, http://precisioninformation.org/?p=32

[6] World Disasters Report, Focus on technology and the future of humanitarian action, International Federation of Red Cross and Red Crescent Societies, 2013

[7] Google Crisis Response Tools presentation, http://www.google.org/crisisresponse/

[8] Careem, M.; De Silva, C.; De Silva, R.; Raschid, L.; Weerawarana, S., "Sahana: Overview of a Disaster Management System," *Information and Automation, 2006. ICIA 2006. International Conference on* , vol., no., pp.361,366, 15-17 Dec. 2006

[9] Ushahidi Platform, http://www.ushahidi.com

[10] How Crisis Mapping Saved Lives in Haiti, National Geographic, http://newswatch.nationalgeographic.com/2012/07/02/crisis-mapping-haiti/

[11] S. Shen, N. Michael, and V. Kumar, "Autonomous indoor 3D exploration with a micro-aerial vehicle," in Proc. IEEE Int. Conf. Robot. Automat., St. Paul, Minneapolis, 2012

[12] N. Michael, S. Shen, K. Mohta, Y. Mulgaonkar, V. Kumar, K. Nagatani, Y. Okada, S. Kiribayashi, K. Otake, K. Yoshida, K. Ohno, E. Takeuchi, S. Tadokoro, "Collaborative mapping of an earthquake-damaged building via ground and aerial robots", Journal of Field Robotics, Volume 29, 2012

[13] Raffaello D'Andrea: The astounding athletic power of quadcopters, TED conference