smart Emergency Response System (smartERS) – the Oil Spill use case

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Abstract

Thanks to the huge progress within the last 50 years in Earth Observation, Geospatial science and ICT technology, mankind is facing, for the first time, the opportunity to effectively respond to natural and artificial emergencies such as: earthquake, flood, oil spill, etc.

Responding to an emergency requires to find, access, exchange, and of course understand many types of geospatial information provided by several types of sensors. Majors oil spills emergencies as, the Gulf of Mexico (Macondo/Deepwater Horizon) in 2010, the sinking of the oil tanker Prestige in 2002, have offered lessons learned and identified challenges to be addressed.

Interoperability provides the principles and technologies to address those challenges. Since years interoperability has been developing based on traditional Service Oriented Architecture, request/response communication style, and implemented through Spatial Data Infrastructures. The experience handling oil spill responses shows that emergency services based on SDIs have some limitations, mainly due to their real-time peculiarity. Moreover despite the effort that Private Sector and Public Administrations have been putting since years, the goal to provide an exhaustive picture of the situation during an Emergency Response is still far to be reached.

We argue that to achieve this goal, we have to frame the problem in a different way. Emergency Response is not just sensing; it should be smart enough to encompass intelligent actions. In this paper we propose a set of potential directions that could help in improving the emergency awareness at sea during an emergency through the rapid collection and processing of contextual data from different sources. This would automatically lead to more effective and efficient response operations. The gaol of this paper is to define what a "smart Emergency Response System" (smartERS) should be.

Keywords: Emergency Response for Oil Spill, Interoperability, Internet of Things, Citizen Sensing, Semantic Web, Event-Driven Resource Oriented Architecture.

1 Background

For understanding the context of this work, it is important to familiarise with the processes that an Emergency Response comprises, the people involved, the type of oil spill emergencies that could occur, the major accidents happened so far, and the response currently in place in Europe.

1.1 Processes

An Emergency Response process comprises the following phases (as in Figure 1):

1. Preparedness. This phase is characterized by planning the emergency capabilities, the data identification and acquisition.
2. Response. The focus of this phase is to put in place the initial response activities, damage limitation, resource acquisition.
3. Recovery. This phase deals with the actions for containing and cleaning-up the contaminated area.
4. Mitigation. The necessary measures to mitigate the risk that an accident could happen are put in place during this phase.

Figure 1: Emergency Response lifecycle

1.2 People

The management of an emergency is led from three different coordination teams: operational, tactical and strategic.

Operational coordination takes place at the location of the accident; the strategic and tactical coordination take place in coordination centres.

The strategic coordination team decides what should be done for responding to an emergency, and how to communicate to the public. The tactical coordination team turns the orders from strategic team into actions to be executed by the operational team, which responds to the emergency situation.

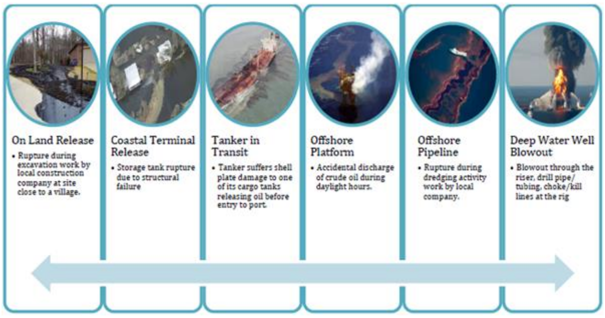
(*) The findings, interpretations and conclusions expressed in this paper are entirely those of the author and should not be attributed in any manner whatsoever to EMSA.

1.3 Oil Spill Response

Emergency Response is a vast area that involves many aspects and scenarios. Within this work we will study Emergency systems for Oil Spill Response (OSR).

There are several origins of spill to target (as in Figure 2).

Figure 2: Oil Spill origins



We deliberately focus our attention on: "tanker in transit" and "offshore platform". Limiting this work at these accidents helps to make specific example, and moreover we can benefit of the large literature published on these subjects. The "Gulf of Mexico" (Macondo/Deepwater Horizon) accident in 2010, the sinking of the Prestige oil tanker, releasing oil spill off the coast of Galicia in 2002, have had far-reaching consequences in prompting the re-examination of Emergency Response operation, creating an unprecedented need for information on a real-time basis.

1.4 Common Operating Picture

Since years the emergency coordination teams have been developing the concept of *Common Operating Picture* (COP) defining a set of requirements that such tools shall meet [1].

A COP is a computing platform based on Geographical Information System (GIS), it provides a single source of data and information for situational awareness, coordination, communication and data archival to support Emergency Response personnel and other stakeholders involved in, or affected by, an accident.

A COP is established by: contextual considerations, a set of maps, and performance requirements.

Foremost standards and data used to develop a COP are driven by several contextual considerations:

- Origin of Spill.
- Land-Based vs. Marine.
- Arctic vs. Temperate, Desert or Tropical.
- Static vs. Real time information.

In Emergency is crucial to agree about the semantic of symbols, to avoid misinterpretation and reduce the response time, for this reason emergency maps templates shall display the geospatial information to the end users in a coherent style.

Finally a COP shall provide continuously updated overview of an accident, through the following functionalities:

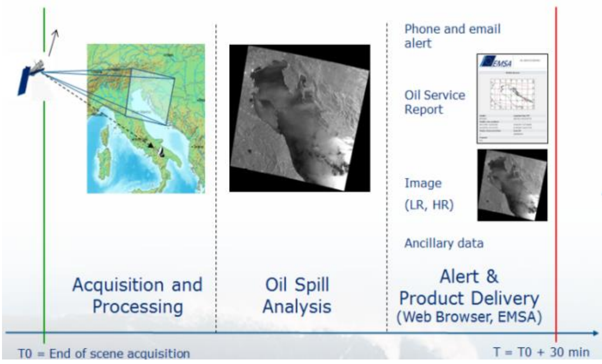
- Access authoritative information.
- Integrate diverse information from multiple organizations.
- Display map templates.
- Handles multiple coordinate reference systems.
- Supports customization of map.
- Ingests near real-time, as oil spill observations and trajectory predictions, vessels positions, etc.
- Supports review of a historical record.

1.5 European reaction

In September 2005 the European Parliament and the Council adopted Directive 2005/35/EC [2]. This Directive tasked the European Maritime Safety Agency (EMSA) to develop the CleanSeaNet service [3]. Based on the acquisition and processing of satellite images, see in Figure 3, CleanSeaNet offers assistance to participating States for the following activities [4]:

- identifying and tracing oil pollution;
- monitoring accidental pollution during emergencies;
- contributing to the identification of polluters;

Figure 3: CleanSeaNet



The CleanSeaNet service is based on radar satellite images, covering all European sea areas, which are analysed in order to detect possible oil spills on the sea surface. When a possible oil spill is detected in national waters, an alert message is delivered to the relevant country. Analysed images are available to national contact points in near real time: within 30 minutes of the satellite passing overhead. The service aims to strengthen operational responses to accidental and deliberate discharges from ships. When an oil spill is detected a correlation against the positions of vessels (SafeSeaNet) within the area takes place.

Approximately 2,000 images are ordered and analysed per year. During the first three year of the CSN service (from 16/04/07 to 31/12/09) 5816 satellite images were delivered, 7193 possible spills detected, of which 1997 were verified on site, and 542 confirmed as being mineral oil [5]. These figures give the relevance of the problem, and the gap between spill detection vs validation.

2 Enablers

Despite the effort that public and private organizations have been putting in place since years, there is still lot of work to do for managing efficiently at oil spill emergencies [6]. The recent report ¨Common Operation Picture for Oil Spill Response" [1] summarize the challenges:

- Lack of agreement on what data needed to be tracked and transmitted.
- Vast geography of the response area.
- Lack of availability of appropriate interoperable communications technology.
- Limited ability to push real-time data throughout the response organization.
- Different computing standards.

Bearing in mind these challenges, within this section we intend to identify scientific topics and technological assets for enabling a smart Emergency Response.

2.1 EU Policy Framework

Through standard web services and common data models, *interoperability* provides means to access and share information among several stakeholders with the ultimate goal of improving the situational awareness and increasing the efficiency [7].

In the European Union (EU), the European Commission is guiding the process of improving interoperability among its Member States, Institutions, Agencies (hereafter called Public Administrations) through several Directives such as INSPIRE [8]. Within the maritime context interoperability is supported by the development of the Common Information Sharing Environment (CISE) [9], as part of the Integrated Maritime Policy [10] and the EU Maritime Security Strategy (EUMSS, [11]).

2.2 Data Sources

Public Administrations and Private Sector agree that the information provided by their services, "Authoritative Information", is often not enough to make coordination centres situational aware during an emergency [12]. For example satellite images might be unavailable for hours, even days, due to the orbital limitations of revisit time [13]. So they conclude that there is the need to integrate additional data sources, preferably in real time [6].

Geographic information created by amateur citizens, often known as volunteered geographic information (VGI), since years has been showing to be an interesting data source in case of emergency [14], particularly valuable during the response phase [15]. VGI can complement traditional Earth Observation data to improve the awareness of accidents [16]. However VGI is still regarded as insufficiently unstructured, not documented, and poorly validated according to scientific standards. To mitigate this issue, several researches have been exploring to feed Spatial Data Infrastructure (SDI) with reliable VGI [17]. These efforts are summoned under the term *Citizen Sensing* [18]. This concern about VGI quality has led the discussion into a classification exercise.

When Data is collected for a specific purpose by volunteers through established community, is called *Participatory Sensing* [13]. Instead *Collective Sensing* is defined as a large amount of anonymous data extracted from social media [19].

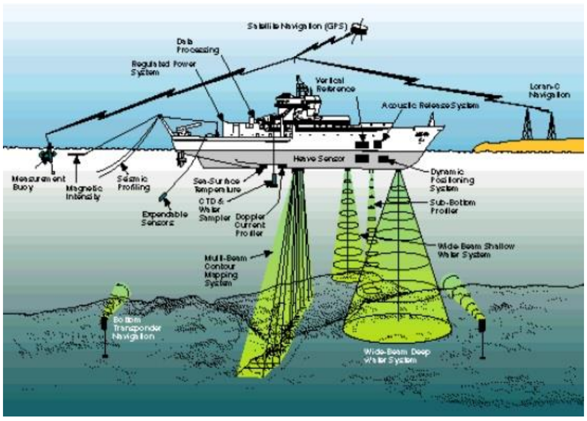
Whereas Collective Sensing can significantly improve the efficiency of Emergency Services, increasing the timeliness to detect an emergency and decreasing the cost, is evident that the risk to take actions based on Collective is higher than on Participatory Sensing. For example, relying on environment friendly community (Participatory Sensing) for tasking acquisition of satellite images for oil spill monitoring is more trustable than on the grounds of tweets (Collective Sensing). Hence in 2012 the US National Response Team prepared a document on the "Use of Volunteers: Guidelines for Oil Spills", outlining ways in which oil spill responders can move toward improved citizen involvement before, during, and after an oil spill [20].

Also Private Sector is publishing a huge amount of Sensing information (remote, citizen, etc.) that until now only Public Administrations were capable to deliver. This scenario is creating an unprecedented volume of quite high quality data ready to be integrated into Emergency Response System. For example Global Fishing Watch is a web service to show the track-able fishing activity in the ocean [21]. Global Fishing Watch implements a behavioural classification model over 3.7 billion data points, from two years of satellite Automatic Identification System (AIS). Indeed this approach has been explored by several research works [22]. It is clear that such service was not designed for Emergency Response, however it provides freely accessible position of vessels in real-time on open seas, which can be reused for oil spill response.

As matter of fact the information provided by Public Administration through SDI, or by citizen through smartphones, or again by Private Sector through geospatial services can be seen as part of a unique global network of *Sensors* [23]. Such network of sensors constantly provides measurements and observations.

To embrace this network of sensors concept for oil spill responses would be necessary a massive number of sensors deployed at sea. It will need time, resources, and strong support by policy makers; unless we realize that all over the world there are already an enormous number of sensors, the vessels. The European seas are cruised daily by around 50.000 vessels. Vessels embed several sensors to measure the bathymetry, the positions, the course, the speed.

Figure 4: Vessels as Sensors



Plugging fluorometer sensors into vessels can provide a comprehensive coverage of sea for detecting spill [24]. Embedding sensors data into AIS message would mean that vessels could deliver sensing information with a refresh rate in the order of minutes. Thinking in this term means to see a *Vessels As Sensors* (Figure 4), that collect data to be possibly published on internet. Such amount of data should be made open so that “anyone can freely access, use, and share” (*Open Data*) [25] creating new solutions for oil spill responses.

To make use of this plethora of different sensors the geospatial community (OGC) has introduced a framework of standards under the umbrella of Sensor Web Enablement (SWE) [26]. SWE defines service interfaces which enable the usage of sensor resources, hiding the complexity of the various devices [27], through the following functionalities: discovery, access, tasking, as well as eventing and alerting [28].

3 smart Emergency Response System

Whether it is doubtless that interoperable sensors based on standards (e.g. SWE) have been contributing to get a better situational awareness picture, the integration among different organizations for Emergency Responses purposes requires a strong effort for establishing Service Level Agreements. Thus the major criticism about this approach, interoperability based on standards, is actually its sustainability. There is room for a new strategy. We believe that rather than to see standards as an overarching approach, we should consider all sensing sources as self-governing and “interlink-able”.

Nowadays the data provided through multi sensors has in common the same infrastructure: the World Wide Web. This interconnection of uniquely identifiable embedded computing devices within the existing internet infrastructure is called *Internet of Things* (IoT) [29].

Data mining of geospatial data provided through IoT in real time will enable to filter out the less relevant information and turn into a meaningful source the rest. Knowledge discovery algorithms aim at mapping large volumes of data into forms and structures that can be more compact, abstract and possibly more useful to the target application [30]. As an example, vessel self-reporting data such as AIS can be pre-processed and transformed into a set of tracks that can then be clustered in order to extract common routes or patterns of vessel activities at sea [31]. This approach is useful not only to build a better situational understanding for an emergency, but could also be the basis to frame behavioural anomaly detection or vessel route prediction [32], applicable for example for oil spill prevention.

This concept will empower intelligent Emergency Response System to perform actions, not just sensing things.

Since years SDIs have been developing taking into account Service Oriented Architecture based on specific paradigm: "publish, find and bind". Resources, as dataset, need to be published according to specific standards into a catalogue services (publish), to be discovered based on pre-defined criteria (find), and finally consumed by a client (bind).

On the grounds of the experience running Emergency Responses, the solution based on SDI has the following weaknesses: high complexity to bind new services in real-time; deficit of information provided, and quite high maintenance costs [6].

We believe that the architecture for smartERS will likely be an instance of *Event-Driven Resources Oriented Architecture* [33]. When an emergency will be detected a webcasting server ostensibly will "push" information to actors (services, avatars), that making use of ontologies [34] can browse dynamically interlinked structured data (*Semantic Web*) [35], so that emergency contextual information can be readily acquired and interpreted by machines through *geospatial mining* algorithms [36], and finally integrated into smartERS for trigger intelligent actions. For example meteorological and oceanography data such as wind fields, surface waves, currents, bathymetry is crucial to characterise the emergency and help decision maker. This data can be used to better understand the source of the emergency (e.g. origin of the oil spill), as well as to predict its evolution (e.g. where the spill drifting). The former is necessary to understand the causes of the event, whereas the latter is useful to estimate its potential impact.

4 Conclusion

Emergencies do not know borders, in particular at seas. Therefore we underline the need to define in Europe a framework to implement emergency responses systems in order to enable harmonized national responses. The framework shall comprise: (i) guiding principles; (ii) reference architecture; (iii) operational workflows (for example see the US National Emergency Framework [37]). Within this context, smart Emergency Response Systems could contribute not just to collect data and observations, but can help in performing intelligent actions. Establishing such Framework in Europe will enable policy makers to foster governmental initiatives, the private sector to do investments, while empowering citizens to participate actively in emergency responses.

We are living in the era of *Big Data* [38], where data Volume, Velocity and Variety is so huge that we can take advantage of this unprecedented amount of information to conceive new Emergency Response Systems in order to, for the first time, “smartly” respond to natural and artificial emergencies.

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