C2-SENSE: The Emergency Interoperability Framework and Knowledge Management

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Abstract: Hazards and disasters caused by nature or humanity require great efforts that often do not recognize international borders. In such crisis situations there is a great need for tools that facilitate communication, resource management and offer decision making solutions in organizational structures.

The Command and Control C2-SENSE[1] Framework aims to develop a (GIS) tool for such extreme needs. The system gathers sensor network data from disaster affected areas and presents them to the user of the system. During the process, sensor data are homogenized (due to different sensors' output formats) and semantically enriched (e.g., every datum is geotagged) according to OGC standards. The further process of data analysis is tailored for the specific user profile (police department, hospital, ambulance, fire department), and relevant information is visualized on appropriate maps.

The central part of the system is the *Knowledge Interoperability Layer*, in which the data are processed for main analysis and visualization. The layer comprises several components responsible for sensor management, sensor data requests, and map requests, data and map mash-ups and visualization. The components together provide robust, accurate and reliable crisis situation information. Thus the user is provided with relevant information, thereby saving time and energy, and thus being more able to focus on decision making, vital in hazard and disaster situations.

1. Introduction

Effects of natural and human caused emergencies and disasters are directly manifested in terms of loss of human lives, damages to infrastructure and in long-lasting economic effects. Flooding, forest fires, volcanos, droughts, but also industrial accidents are some of the major examples of emergency causing situations. Moreover, it is recognized that disasters do not respect national borders, leading to situations requiring great cross-border efforts (see (1), (2), and references therein).

When considering the frequency of emergencies in the near future, the currently available prognoses are suggesting that we have to expect an increase in number and severity (3). This is very evident in Figures 1 and 2, where frequency of floods is shown for the last six decades, for Europe and the World respectively. The figures

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[1] www.c2-sense.eu

also show that the costs related to damages due to floods are following the trend. This is possibly caused by the combination of the severity of floods and the respective infrastructure damaged.

Regardless of the true cause for the increased number of disasters, which may be human or naturally caused (4), it is a forth standing challenge for many countries. A natural response for a more hostile environment is to be more prepared for crisis situations. Studies have already shown that preparation costs can be a lot less than the damage costs due to a disaster, for which one is not prepared (see (5) and references therein). Preparation process, besides planning and construction works, usually includes some form of Command & Control (C2) systems, which decreases reaction and communication time and increases the efficiency of communication, provides the access to relevant sensor data, and provides the visualization of the emergency area in order to allow proper decision making.

The C2-SENSE Command and Control Framework aims exactly on developing a system for such extreme needs. The system provides the user with the real-time data and analysis of the emergency situation, and offers a tailored and profile-based interoperable environment for communication, information sharing, and support for decision making.
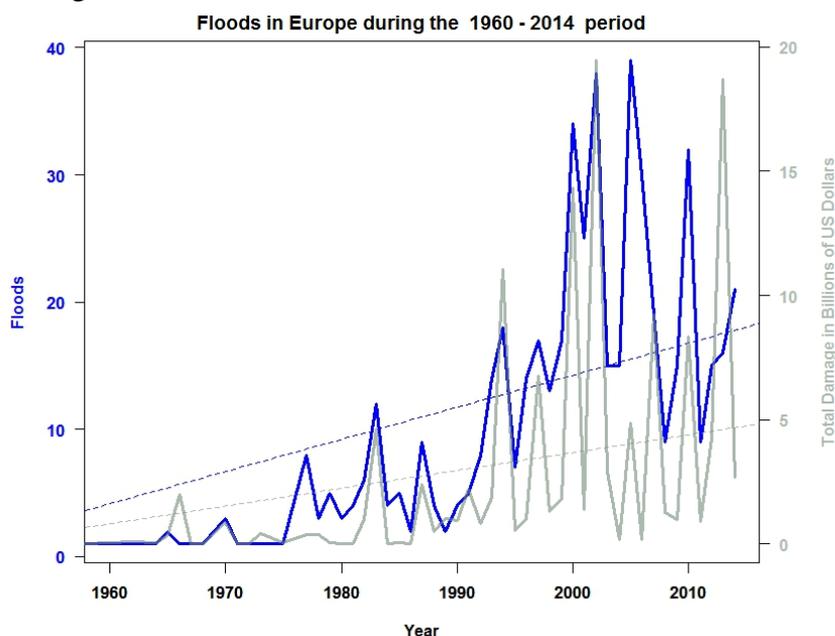

Figure 1: Floods and flood-related damages in Europe for the 1960-2014 period. The frequency of floods is shown in blue, while the total damages related to floods are shown in green colour. The two dashed lines are a linear fit to the data and represent a trend of an increasing flood frequency and total damage costs. The data are taken from emdat.be.
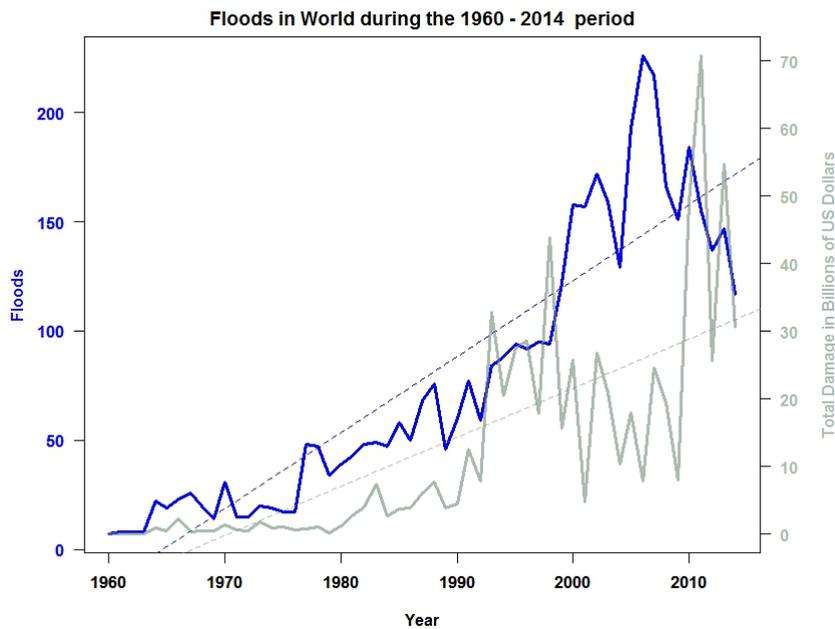
Figure 2: Floods and flood-related damages in the World for the 1960-2014 period. Color coding is the same as in Fig. 1. Similar to the Europe, a trend of an increasing flood frequency and damage is observed. The data are taken from emdat.be.

2. Emergency and Disaster Management Framework C2-SENSE

2.1 Knowledge Management

2.1.1 Open Issues in Emergency and Disaster Management (EDM)

One of the major obstacles for an efficient EDM is the flawless and accurate communication among parties involved. Moreover, the exchange of relevant data is a very crucial part of the communication process, as it is the basis for a correct decision making. As aforementioned, disasters tend to occur across borders, being those of countries, states or of similar political and organizational nature. One recent example is the river Danube, which flooded several countries in one of the major floods in Europe during the last 20 years (6). It is therefore important to ease the communication process by removing obstacles based on different languages, cultures, laws, and practices in relevant organizations.

Moreover, it happens often that ad-hoc organizations are initiated during emergency situations, and their integration in a fellow communication and data exchange may be highly relevant for a successful rescue operation. For such cases, an EDM system needs an efficient and secure way of inclusion. In order to solve these aforementioned interoperability issues, C2-SENSE offers a profile based approach.
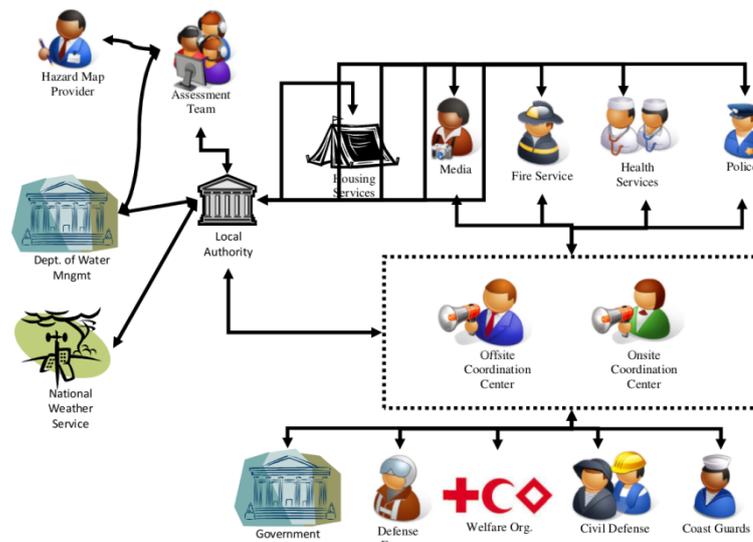
Figure 3: An example of involved parties in an emergency situation. Depending on the country, the figure can be more complex and requiring. For the communication among the parties to occur, agreements are needed. C2-SENSE profiles automate exchange of messages and data. This is specifically important when the emergency is across borders.

2.1.2 Profiles

The communication issue – Depending on the severity of the emergency, there may be many parties involved, such as authorities, relief organizations, police, and health workers, as shown in Fig. 3. At the same time, there should be a hierarchy present, such that there is a possibility for a chain of commands. The questions such as who can communicate with whom, who can send messages, and who is supposed to receive them are all important and can likewise raise security issues. The C2-SENSE system provides a profile-based approach: Each user of the system has been assigned a profile, which defines the communication paths and permissions for and among parties. For example, a volunteering organization may not be allowed to read messages sent by police authorities, due to sensibility of information present in the message (and which is only relevant for higher authorities). Moreover, profiles solve variations in responsibilities that are present among organizations and authorities in different countries.

The data sharing issue – As with the communication (which is also a form of data exchange), there are requirements when considering sharing of data among different users and organizations. This issue is even more severe when considering international crisis management efforts. Again, the C2-SENSE system solves the issue by defining the sharing paths and permissions in user and organization profiles. For example, in a crisis where France and Italy have a joint rescue effort, a sensor data collected by French data centres can only share these data with Italian authorities with whom they have bilateral agreements, and vice versa. In this way, one avoids sharing of possibly sensitive data with unwanted receivers. One can think of many different scenarios where such situation can be critical.

Ad-hoc inclusion of non-standard organizations – With *non-standard* is meant organizations and parties that have emerged right before or during the emergency. Such situations occur for example during floods, where resources such as food and water are collected by newly founded volunteering groups. Again, an administrator of the C2-SENSE system can provide the organization with a profile that enables it to be efficiently involved in the emergency operation. This evolves correct permission and restrictions definitions in the C2-SENSE system.

In all of these mentioned cases, it is crucial to have in mind that complexities of these efforts raise tremendously when cross-border emergencies occur and when the corresponding efforts are initiated. Different laws, responsibilities, languages and cultures all have to be dealt with. For example, a great effort is under way within the project EPISECC (7), in which the focus is set on protocol and network, information, as well as operational interoperability on international level.

2.1.3 Data Management and Analysis

In short, the framework gathers sensor network data from disaster-affected areas and presents them to the user of the system. During the process of data analysis, sensor data are homogenized (due to different sensors' output formats) and semantically enriched (e.g., every datum is geotagged) according to OGC standards. The further process of data analysis is tailored for the specific user profile (e.g., police department, hospital, ambulance, fire department), and relevant information is visualized on appropriate maps (see (8) for references on technologies used in C2-SENSE).

The central part of the total system (see (9) for a full figure) is the *Knowledge Interoperability Layer*, in which the data are processed for main analysis and visualization. As is shown in Fig. 4, the layer is comprised of several components responsible for sensor management, sensor data requests, and map requests (from e.g., Map Services), data and map mash-ups and visualization, and decision making process. The components together provide robust, accurate and reliable crisis situation information. A user is only provided with relevant information, thereby saving time and energy, and thus being more able to focus on correct decision making, vital in hazard and disaster situations.
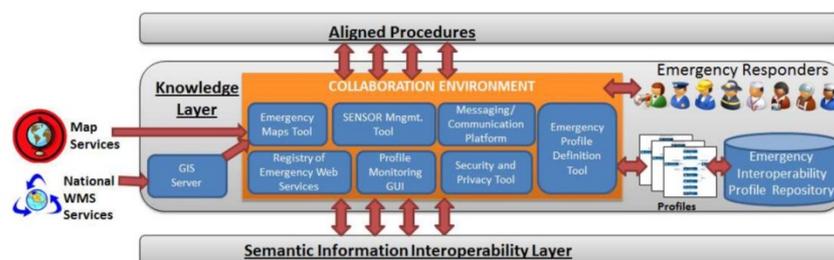

Figure 4: The Knowledge Layer, where all incoming information is put into final processing for presentation on maps. The data are enriched and presented in such a way that it easies decision making.

An example of knowledge management in the C2-SENSE system is as following. A water level flood sensor is recording water level at location <lat, lon>. A datum is sent from the sensor to a C2-SENSE IP-based Gateway, which allows communication with external sensors. Every datum is then formatted to one standard format used internally in the system. The C2-SENSE system needs to communicate with every relevant sensor, but which often deliver data in different formats, and hence is the data formatting and homogenization a very important step in the process. Further, the data are stored on servers, thus making them available for other actions, such as limit analysis, which is about discovering when defined limits are reached (e.g., water levels). Moreover, every datum is enriched in the process with information about the sensor itself, location, and other relevant semantic information. At the end, the data can be visualized by the system's GUI. The main window shows a map requested from standard Map Services, and the data in a form of a feature.

Again, the defined profiles play a crucial role in determining permissions and requests. This is relevant for data, communication and visualization. Police authorities will possibly have a different view of the emergency situation displayed in the C2-SENSE GUI map than health workers, merely because the interest in the information defined in their profiles is not identical (e.g., criminal activities reported in a certain area and number of free beds in a hospital). The reasons for such approach are already aforementioned.

3. Use Case: Italy – France Crossborder Emergency Scenario

In the general C2-SENSE use case scenario[2], the international disaster response operation must secure an earthquake area. The following actions take place in a fictitious European area for a disaster relief:

1. At hour H, an earthquake of exceptional magnitude has occurred in the area of Nice, near the border between France and Italy. The natural disaster impacted the coast within a radius of 40 km. A tsunami of limited amplitude has also flooded the shore.
2. The following information is acquired and estimates are made:
   2.1 *Casualties:* A call in centre has been set up, and first estimates are expected to arrive at H+10, but figures are not reliable, since most of communications and electricity have been cut.
   2.2 *Damages:* Roads and shore infrastructures (ports) have been destroyed and are partially out of order. Several civilian and administration buildings have been destroyed. Local hospitals are out of order. Many civilians are either dead, injured, or homeless. Many fires have been ignited during the earthquake and make difficult rescue operations

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[2] As defined by the joint C2-SENSE partners' efforts. See the c2-sense.eu website for a list of partners.

2.3 *Threats:* Many types of threats have been identified by geologists and architects:
  • Buildings may collapse and block roads or threaten survivals or first responders
  • Ignition sporadic fires, due to electricity and gas and petrol leak.
3. State of emergency has been declared by both French and Italian government.

In such emergency and disaster situation, C2-SENSE can be implemented. The technologies used (see (8)) are both reliable and robust, such that communication can be implemented, sensor data acquired and C2-SENSE managing initiated.

4. Conclusion

Emergency and disaster management is in need of tool that would ease the communication, data sharing among parties, and allow for a more accurate and correct decision making during an emergency. This will not only save lives, but also infrastructure and services that are crucial in the process of rebuilding, and minimize the losses in economic sense.

C2-SENSE takes a profile-based approach, where for each organization or authority a set of permissions and restrictions is defined. It includes communication paths and parties, and data sharing paths and parties, to mention some. Such approach is already used in eHealth domain, and is shown to be effective (10). It is to author's knowledge, however, the first time that such an approach is used in the Emergency and Disaster Management domain.

The possible usage of the C2-SENSE applications' is manifold, due to its generic and yet ad-hoc type of nature. C2-SENSE is generic in the sense that it is able to communicate with all relevant sensors, use technology that is standard, open source and robust, and in a sense that it delivers a tool for decision making. The framework is adaptable and flexible to the needs of future technologies. It is aimed to deal with all type of emergencies, being that of floods, earthquakes or others. The strength of C2-SENSE is that it can be tailored for a plethora of different organizations, even cross-border, while taking into account the different languages, laws and practices.

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