Advanced Cyber Technologies to Improve Resilience to Emergencies

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Introduction

Despite major efforts of international disaster management communities, current systems for risk management are still limited in their effectiveness. Despite technological progresses are registered and large amounts of data are available, there is no platform that integrates and analyses in real-time most useful data to improve prediction and management of natural hazards driven disaster. On the other hand, the need for systematic data collection for disaster mitigation and prevention is an increasing need for both development and response agencies. In the past, data needs were addressed on an ad hoc basis, which included collecting information at the time of emergency. However, there is a growing understanding that integrated information and communication technology (ICT) systems proving data collection, analysis, and management can help both short and long-term development goals, enhancing the identification and management of disaster risks.

Among currently available innovative solutions, we would like to present I-REACT emergency management system, developed by a consortium of international partners within the EU Framework Programme for Research and Innovation H2020. I-REACT (Improving Resilience to Emergencies through Advanced Cyber Technologies) integrates existing services, both local and regional, into a platform that supports the entire emergency management cycle. In particular, I-REACT implements a multi-hazard system with a focus on main climate-induced natural hazards such as floods, fires and extreme weather events.

Leveraging on innovative cyber technologies and ICT systems, the I-REACT framework is designed as an articulated and modular system based on different components. The system integrates many different information sources, including Copernicus assets such as EMS maps, early warnings from the EFAS and EFFIS, satellite data (Sentinel), social media streams and crowdsourced information from emergency responders and citizens. All this information is merged to provide added-value products and operational solutions such as a decision-support system for authorities and an app for citizens along with wearable devices and smart glasses designed for first-responders. The latter are able of high-precision positioning functions (thanks to Galileo, EGNOS and Augmented Reality functionalities) to issue hands-free reports.

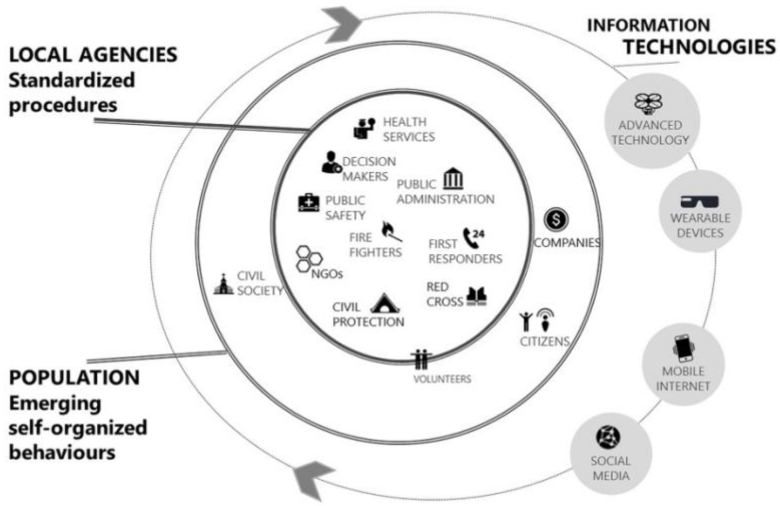
Thanks to this architecture, I-REACT is and integrated system able to manage and digest big data and provide greater emergency anticipation through accurate weather forecasts coupled with historical knowledge, satellite and risk maps, crowdsourced reports, and social media information. It includes standard modules and novel components capable to interoperate with existing systems, instrumental to future exploitation, making it able to adapt and respond to different needs.

In the following sections, we describe the overall I-REACT concept and Big Data framework and how we designed it by using a user-centred approach. Then, we outline how people can be engaged and support emergency management by means of social media and crowdsourcing, which are two key modules of I-REACT based on innovative algorithms and methodologies designed by the I-REACT research team.

The I-REACT Big Data framework

To design an innovative and effective integrated solution for emergency management a user-centred design approach was followed, targeting the needs of both first responders and citizens. It included the definition of user requirements that was finalized within a two-day user requirement workshop, which was organised in September 2016 at UNESCO Headquarters in Paris. It brought together key actors in the Disaster Risk Management (DRM) cycle (see Figure 1), including policy-makers, emergency service providers, science and technology experts from eleven European countries. The workshop aimed to gather the most urgent needs in DRM, to assess the implementation gaps in current operational procedures, and to co-design some key features of the I-REACT system, e.g. the data collection and visualization.

Figure 1 - Disaster Risk Management (DRM) ecosystem

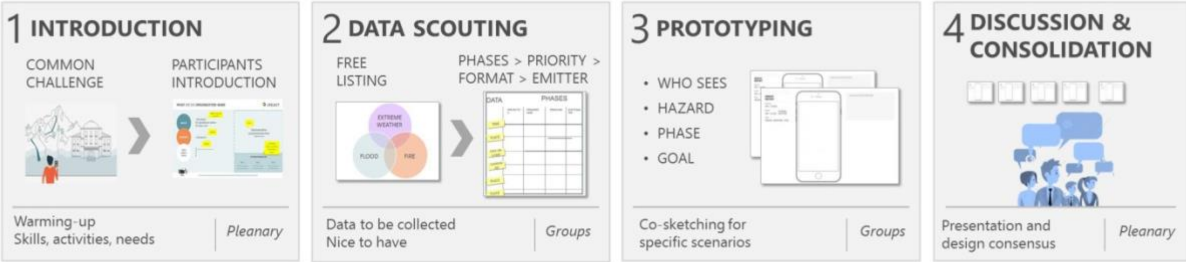


The co-design phase was realized according to a specific methodology, which was created to address the challenge of including citizens into emergency management procedures through a distributed data collection and verification process. Such methodology, sketched in Figure 2 and fully explained in a recent paper from I-REACT researchers (Nguyen et al., 2017), allowed to gather all inputs required to design the I-REACT mobile application and to identify end-users' needs and requirements. The summary of the main user requirements, identified by means of 166 questions, are publicly available at the following link: http://www.project.i-react.eu/wp-content/uploads/2017/09/summary-of-user-requirements.pdf. The main outcomes are:

- Operational management is the biggest challenge in emergency response
- Coordination is the most important goal in emergency procedures
- Images and videos are the most valued information during emergencies
- Wearable devices are the top most valued information channel in emergencies

The outcomes of the workshop can be a valuable input not only for I-REACT but also for any other ICT system focused on natural hazard management.

Figure 2- Overall diagram of the proposed co-design solution



During the workshop, end-users were able to indicate the priorities for implementation but also the weaknesses and the threats that can impair the introduction of innovative technologies into the disaster management. These issues are not strictly related to technology capabilities or maturity but they are more closely associated with organizational, institutional and cultural aspects. In these terms, the end-users input went beyond the expectations. They provided their wishes in terms of technology opportunities together with a vision about the criticality to integrate them on their standard operational procedures (SOPs).

All outputs of the innovation design phase, has been used to drive the execution of three technical work packages, based on a "Plan-Do-Test" agile approach, which were aimed to create all the components of the I-REACT Big Data architecture. The first work package focused on the integration of existing services, open and linked data. Services and systems offered by the Copernicus programme have been extensively integrated, including the Copernicus Emergency Management Service (EMS), the European Flood Awareness System (EFAS), the European Forest Fire Information System (EFFIS), and data from Sentinels (1 and 2). I-REACT fully leverage on the availability of open and linked data. Open Street Map and the Global Settlement Layer published by the Joint Research Center were used to compute the exposure layer for risk forecasts, while other key datasets published from the European Environmental Agency (EEA), such as the EU Digital Elevation Model and the Corine Land Cover, were used to compute flood and fire extension forecasts. Furthermore, automatic data chains have been implemented for Sentinel 1 and Sentinel 2 to allow fully automated mapping for flood delineation and burned area, respectively. A database of historical emergency events has been built and integrated into the I-REACT Big Data platform. The second technical work package was focused on predictive models, including weather and climate forecasts, extreme weather event detection, flood and fire nowcast and forecast, risk forecasts, and a social media data engine capable to extract and classify Tweets in real-time, retaining only informative content and detecting the occurrence of emergency events. The objective of the third technical work package was twofold: the realization of the I-REACT Big Data and Service Oriented Architecture and of mobile solutions exploiting advanced cyber technologies. The I-REACT mobile solutions include: a mobile application for citizens and first responders that allows real-time bidirectional communication between the field and the control centre; a wearable device for accurate positioning able to benefit from multi constellation GNSS systems including Galileo and to work also in indoor search and rescue scenarios thanks to a novel Ultra-Wide Band positioning system, an Augmented Reality application for Smart Glasses to allow professional responders to see mission critical information directly in their field of view and to submit reports without using their hands; a drone ecosystem supporting both light quadcopters and fixed wing drones were enhanced and integrated in order to allow real-time communication during crises while reducing the consumption of bandwidth. The main novelty of I-REACT is the effective integration of several state-of-the-art modules, which cover all the emergency management phases.

Specifically, the I-REACT framework serves as a system during three key emergency management phases, namely Prevention, Preparedness (early warning), and response. The management of such phases is indispensable to achieve effective results. In fact, the availability of a single system, which is able to cover all key processes, provides better anticipation and more reactive response by exploiting in each phase the input of the previous one. Moreover, the availability of a single system integrating all the required data and services, instead of many ad hoc systems provided by different vendors, provides a better user experience to users, who are not requested to use systems of different providers with different interfaces.

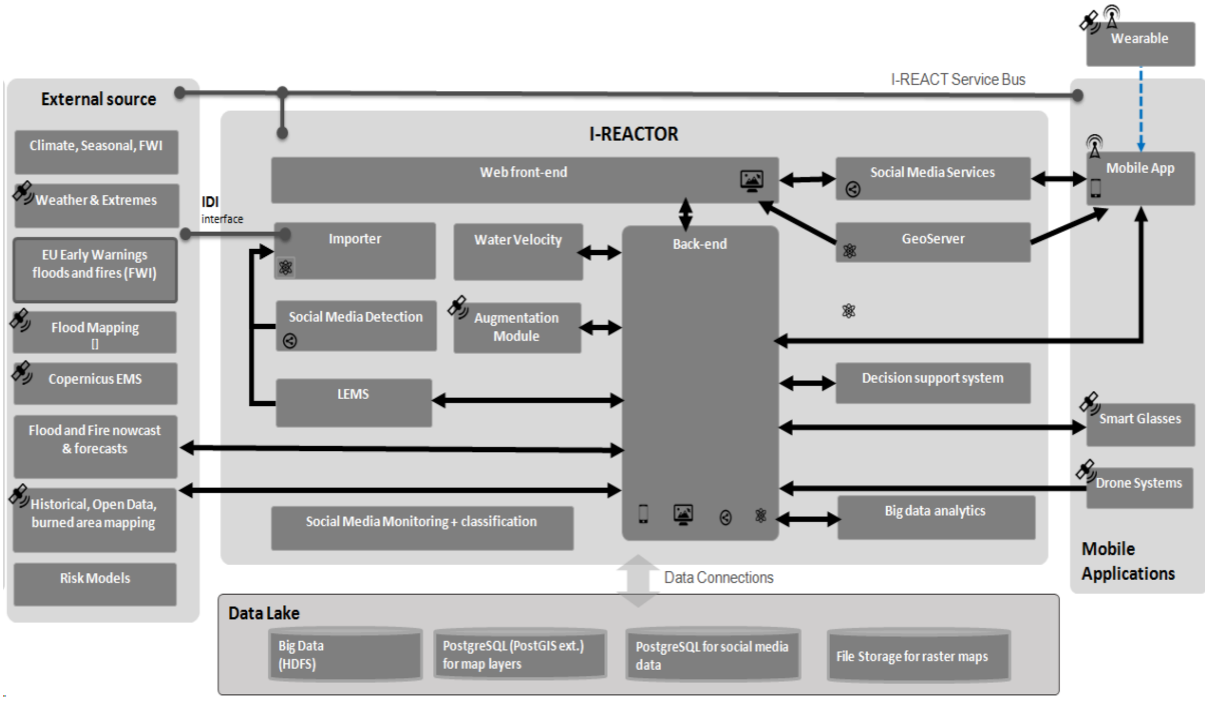
The first emergency management phase mainly deals with the preparation of a community to eliminate or reduce the impact of future disasters. For this purpose, the I-REACT platform uses Big Data analytics frameworks to process historical data, real-time reports, weather data and satellite observations to derive detailed statistics and accurate risk maps than can be shared with decision makers. Such data, coupled with a decision support system, allow decision makers to effectively plan prevention measures aimed at increasing the resilience to future disasters. Hence, medium- or long-term prevention actions can be based on the statistics computed by I-REACT.

The second phase in the emergency management cycle is the preparedness phase. During this phase, the coordination between governments, civil organizations and citizens is promoted to get ready to an upcoming emergency. To reach this objective, I-REACT system analyses weather forecasts from both local and European early warning systems, such as the European Flood Awareness System (EFAS) and the European Forest Fire Information (EFFIS), and warnings extracted from social media or received through crowdsourced reports from authorities and citizens using the I-REACT mobile application. In this phase, the involvement of citizens is crucial since they can provide actionable real-time information using social media platforms (Twitter) or the I-REACT mobile application, which is specifically designed for sharing information related to natural hazards (e.g., floods, fires, and earthquake). The I-REACT mobile application includes a gamification approach that is used to establish a reputation system within the I-REACT community and to inform citizens with base know-how about natural hazards and about the best practices in terms of preparedness actions.

The third phase is the emergency response phase, in which an effective reaction to an ongoing natural hazard, first aid and evacuation are crucial. To help on-site operators, I-REACT allows getting a quick and complete operational picture thanks to the ingestion of real-time reporting from different sources, including mobile phones, drones, and augmented reality devices, and the integration of such reports into nowcast and forecast models. I-REACT includes a web-based control center that can visualize in real-time all collected data, while providing mapping capabilities. Command and control functionalities have been also included to let decision makers assign missions to in-field agents and volunteers and monitor their progresses. To improve self-protection behaviour and reduce exposure, I-REACT supports public authorities by enabling them to send geo-located warnings and alert to citizens with updated information and instructions.

To address all the issues related to the three phases discussed above, and the sub-activities of each phase, a set of integrated modules have been designed, implemented and integrated in the I-REACT framework. Specifically, the architecture of the I-REACT framework consists of several components, each one designed for a specific activity associated with the emergency management cycle. Specifically, I-REACT is characterized by a set of external modules, each one designed to collect or provide data from an external source (e.g., Copernicous EMS) or prediction algorithm (e.g. risk forecast). All the gathered data are integrated and stored in a data lake by exploiting a Big Data solution. The data lake stores raw historical and real-time data, statistical information computed from the raw data, prediction models, etc. Once data have been collected and integrated, specific modules, provided as services, are used to support first responders and citizen before and during emergencies. Figure 3 reports the architecture of the I-REACT systems and its main modules.

Figure 3- I-REACT architecture



To validate the effectiveness of the I-REACT system, several test cases as well the direct involvement of end-users, namely public authorities, emergency responders and volunteering organizations, has been foreseen. Five demonstrations (in Croatia, Italy, UK, Spain, Finland) were successfully executed. After each demonstration, a user workshop was organized to gather feedback that will be used to improve the system. The main outcomes of the demos are:

- The usefulness of the app that allows sharing instantly with the control room measurements (e.g., the water level) and pictures of flooded roads or people to be rescued, engaging not only first responders but also the citizens themselves.
- The possibility for first responders to receive and provide information by means of wearable devices and augmented reality glasses.
- The informativeness of the tweets, which are automatically selected in real-time by means of the social media module. That module provides information that is extremely useful for the management of the emergency, for instance by highlighting critical situations before the official channels.

More details about the Croatia Demo and its outcomes are reported at the end of the document, after the description of the most useful and innovative I-REACT modules.

Social media data for emergency management

People use social media to provide information about the events occurring around them. In the last years, we witnessed an increasing usage of social media for sharing information about natural hazards. Frequently, the information provided by means of social media allows identifying an emergency situation even earlier than "official communication channels". For this reason, the I-REACT system contains also a module in charge of collecting and analyzing social media data (e.g., tweets). The automatic analysis of tweets by means of machine learning algorithms and advanced semantic techniques allows providing useful information to both citizens and first responders during a natural hazard. For instance, Sakaki et al. (Sakaki, et al, 2010) have investigated event detection from social media data. Specifically, Sakaki et al proposed a system to automatically detect earthquakes in Japan using a probabilistic approach on the volume of Tweets. Other interesting works have been done concerning the classification of online data into information classes or topics, which is related to the module that has been developed in I-REACT. The closest work to ours on the emergency context is the one by Caragea et al. (Caragea, et al, 2011), which compares several approaches to classify text messages written during the Haiti earthquake and gathered by the Ushahidi platform into different information classes. However, our solution addresses different types of natural hazards (floods and fires) and uses novel natural language processing (NLP) techniques to analyze the collected tweets. Moreover, our system is able to manage several languages (English, Italian, Spanish, etc.) and hence can be used also in those countries where English is not the official language.

Specifically, the researchers of the I-REACT project designed, implemented and tested a novel solution for early detection and information extraction for natural hazards using social media data and NLP, with a particular focus on floods. By combining weather forecasts and social media, the proposed solution allows to spot ongoing floods and provide real-time data to enhance the situational awareness. The main novelty of the proposed solution is related to the integration of a set of services that links early warning forecasts with social media analysis. Specifically, the proposed solution is a trans-disciplinary methodology that (i) initially identifies areas at risk by exploiting the availability of meteorological forecasts and (ii) starts a targeted monitoring through social media to acknowledge the occurrence of the forecasted weather events, (iii) detects associated natural hazards (e.g., floods), and (iv) automatically filters the social media stream to retain only informative content. Here the concept of informativeness is defined as everything that can be useful to improve the situational awareness for both citizens and authorities about an emergency event.

Two types of end-users are envisioned for the proposed services. Firstly, hydro-met agencies (forecasters) who are interested in receiving in-field observations as acknowledgments of model outputs. Secondly, first responders and local authorities who are interested in receiving event detection alerts and relevant contextual information that can be exploited in order to understand the extent and criticality of an ongoing event when there is no personnel on the field.

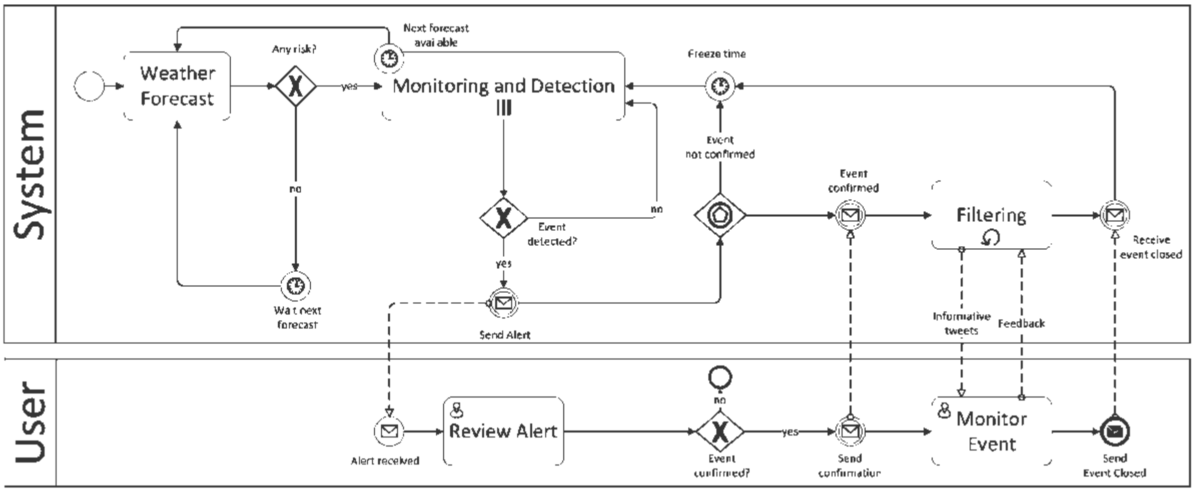
The researchers of the I-REACT project decided to focus their attention on extreme weather events and floods, since they have a high impact on society. Extreme weather conditions can cause disruption of critical infrastructures, damage to private and public assets, and even deaths. The impacts of extreme weather events on the society have been recently investigated in numerous studies, e.g., EU-funded projects EWENT, MOWE-IT and RAIN. Those studies focused on the impacts of adverse weather on the European transportation system and on critical infrastructures, such as roads, railways, electric power supplies and telecommunication infrastructure.

A common practice within national weather services and meteorological forecasters is to issue warnings against adverse weather events based on specific manually defined thresholds for each region under analysis. The warnings typically cover a 24-hour or 48-hour time span. Heavy precipitation events often trigger severe floods that can cause large damages and negative impacts. The main problem of the available systems is the definition of the triggering threshold. A universal threshold cannot be defined and its manual setting is time consuming and prone to errors. To partially automate the threshold setting, a set of formulas can be used to estimate the best threshold for a specific region by analyzing historical data. However, also these solutions can generate a non-optimal solution and some false alerts.

To provide a better warning solution, the researchers of the I-REACT project decided to merge weather forecasts and social media data. The combination of these two types of data generates more accurate warnings.

The proposed methodology has been tested by considering a flood occurred in the north of Italy. However, it is general and can be applied also to other types of natural events.

Figure 4 - Flow of the proposed set of services. The diagram is realized according to the Business Process Modeling Notation (BPMN).



The proposed methodology is based on the following steps:

i. Extreme Weather Forecast
ii. Social Media Monitoring
iii. Event Detection
iv. Informativeness Classification

The flow of the proposed solution is reported in Figure 4. Specifically, the first phase is the Extreme Weather Forecast step that, using state of the art forecast models, performs two weather forecasts per day. The outcome of the forecast is then used to trigger the social media monitoring step. Specifically, if a heavy precipitation event in a specific area is forecasted with a high probability by the first module, the social media monitoring module is activated in order to collect tweets about a potential extreme flood event in that area. The exploitation of the forecast allows the social media monitoring module to focus its analyses only on the subset of tweet associated with the area that will be potentially affected by the flood. Due to the large amount of generated tweets, monitoring all tweets, without enforcing a bounding box, will be unfeasible.

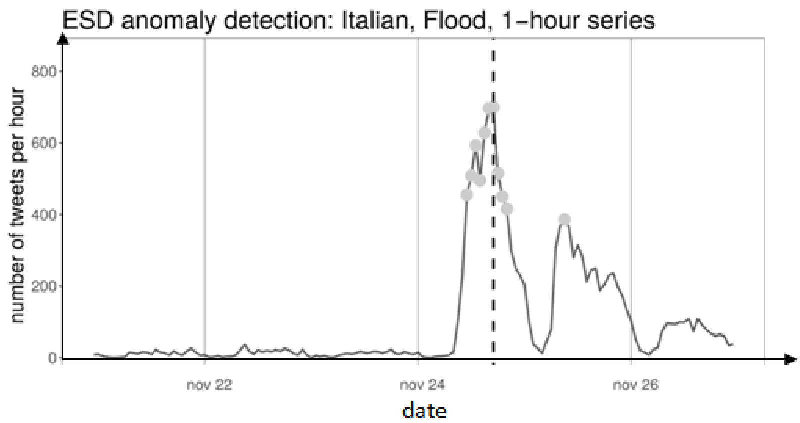
After the triggering of the social media monitoring module, the system starts collecting and analysing tweets in real-time for the area under analysis. To remove noise and reduce the amount of data, the system exploits a semantic and linguistic approach to filter the collected tweets. Specifically, since we are interested in flood events and correlated information, only the tweets containing a specific subset of words semantically related to floods and extreme precipitation events are considered.

Once the set of potentially useful tweets have been collected and stored in a local repository, the event detection step is executed. This step is used to detect emergencies, or anomalous phenomena, i.e., it is used to assess the forecast and identify the actual presence of an extreme precipitation events and correlated critical situations. The event detection step is based on a statistical algorithm that, based on the frequency of the "emergency related" words, identifies critical events. Specifically, the volume of tweets associated with the "emergency related" words is monitored in real-time and the significant increase of it is used to trigger the beginning of a critical weather event.

Finally, once a critical event has been identified by the event detection module, and it has been validated by the end user, the informativeness classification step is executed to extract further useful information from the collected tweets. Specifically, the aim of this step consists in understanding which tweets contain information that can be useful for managing the identified emergency (e.g., a tweet reporting the water level of a river local in the flooded area) and which are useless, even if they are reporting something associated with the critical event (e.g., a tweet containing a message of solidarity towards those affected by the flood). The first type of tweets can be used by first responders to plan how to manage the flood while the second type of tweets is useless for the emergency management. More formally, we consider as informative all contributions that are relevant to the crisis situation and at the same time help to improve its understanding. Hence, Tweets in which the crisis situation is mentioned but do not contain information that is helpful to understand it are not considered informative. The proposed solution is based on natural language processing techniques and neural networks, which are used to pre-process the input data and map them into a multidimensional space where similar tweets are represented by means of points located in the same area. Once the data have been pre-processed, a machine learning algorithm is used to classify each tweet in one of the two classes of interest, i.e., informative or non-informative. Specifically, the ability to discriminate between "informative"' vs "non-informative" tweets is a document binary classification problem. The standard metrics used in such cases are precision and recall. In this case, we focus on the performance of the algorithm for retrieving “informative” tweets. Hence, all the metrics refer to this specific class of tweets. In this case, precision represents the ability of the classifier not to label as “informative” a sample that is “non-informative”, while recall is the ability of the classifier to find all the “informative” tweets. Both measures are useful. However, in this specific scenario we are mainly interested in high recall values because we want to be sure that all the informative tweets will be properly selected and sent to the first responders in charge of managing the emergency. Losing some informative tweets might mean losing some extremely useful information for the management of the emergency.

The described methodology and the software that has been designed to implement it are extremely useful for first responders. The proposed solution allows automatically triggering the beginning of a critical natural event and selecting the small subset of relevant tweets providing useful information for first responders.

Figure 5 - Results of anomaly detection using ESD test on the 1-hour series of Italian Tweets concerning Floods, between November 21st and 27th 2016. Anomalies appear as large dots. First anomaly is detected on November 24th at 11:00 local time. Dotted line marks the Event time according to Copernicus: November 24, 18:00 local time.



The effectiveness and efficiency of the proposed approach has been tested on a real flood event in Italy. However, it is general and can be applied also to other types of natural events. The performed experiments showed the precision of the event detection phase in identifying critical events in advance with respect to Copernicus (see Figure 5) and the quality of the informativeness classification step to select informative tweets and prune the useless ones (the average recall on the tested data sets is 0.73).

Detailed information about the implementation of the described methodology and the results of the performed experiments are reported in (Rossi, et al, 20).

Gamified Crowdsourcing for Disaster Risk Management

The exposure to natural hazards cause different reactions, both at a collective and individual level, including spontaneous and volunteer citizens activities. Specifically, during emergency situations different forms of cooperation take place, including the crowdsourcing, which is envisioned by many disaster risk management approaches to enable citizens to support the emergency management process. However, crowdsourcing is a challenging paradigm as it requires a sustained engagement in order to be effective. The researchers of I-REACT proposed a gamification strategy for crowdsourced disaster risk management services aimed to increase awareness, engagement, and change people behaviours. To the best of our knowledge, this is the first attempt to use a gamification strategy for engaging citizens in the natural hazard context and improve their knowledge and preparedness about natural hazards (i.e., it covers also the prevention and preparedness phases).

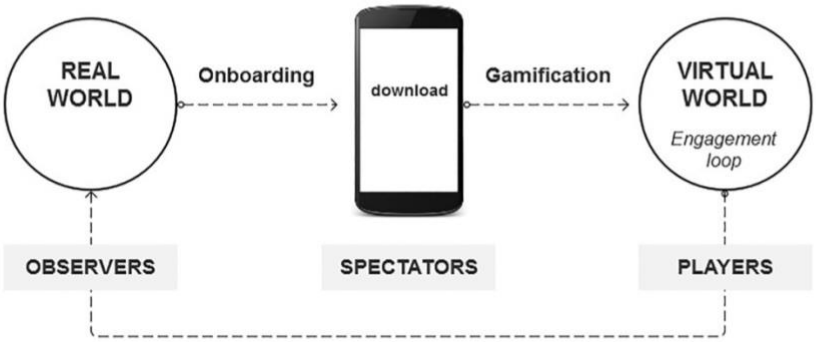
In crisis situations, it has been observed that crowdsourcing is successful in increasing participation and producing useful contents. Hence, most recent disaster risk management (DRM) approaches include the direct participation of citizens during the phases of a natural hazard. Crisis managers can crowdsource hazards monitoring activities to track the current state of the affected areas, perform damage assessments, and localize affected people and resources on the ground. However, the connection between the crowd and disaster risk management professionals is not easy. For this reason the researchers of the I-REACT project designed a specific gamification strategy for crowdsourcing DRM applications encompassing data collection and validation (Frisiello, et al, 2017). The gamification strategy proposed in I-REACT aims at involving people to cooperate also in the prevention and the preparedness phases, when crowdsourcing monitoring activities may results particularly helpful. To achieve these objectives, three specific goals have been set and entrusted to gamification:

i. Citizens awareness: raising the people’s interest and attention on environmental risks and informing them about natural hazards is of paramount importance to obtain valuable and actionable data.

ii. Citizens engagement in reporting: the in-field data collection (reporting) is the key added value that crowdsourcing can provide to DRM because it can achieve distributed monitoring, delivering both high quantity and high accuracy of information.

iii. Reports validation: the data collection process requires a validation mechanism because citizens-generated information can be inaccurate, inappropriate, or counterfeit.

Figure 6 - Actors in the gamified crowdsourcing scenario.



Another important step in the design of an effective gamification strategy is the identification of the actors we want to reach and involve (see Figure 6). Specifically, a gamified ecosystem has to take in account the following types of actors:

i. Players : the active performers that compete in the experience and are highly immersed;

ii. Spectators : individuals who are part of the real environment (e.g. audience, supervisors, etc.), not directly competing, and whose presence influence how the gamified experience works;

iii. Observers: external individuals who are passively involved in the experience. They have no direct impact on the gamified experience but they are able to watch it from the outside. Their presence and amount are can affect the popularity of the experience, and they can also be considered as potential players or spectators.

Within the DRM context, the main goals are (i) raising awareness on natural hazard, (ii) stimulate protective behaviours toward both the environment and people, (iii) enable an effective cooperation with emergency organizations. We mapped such goals to competences, which are achieved by performing a set of specific actions. We identified the following competences:

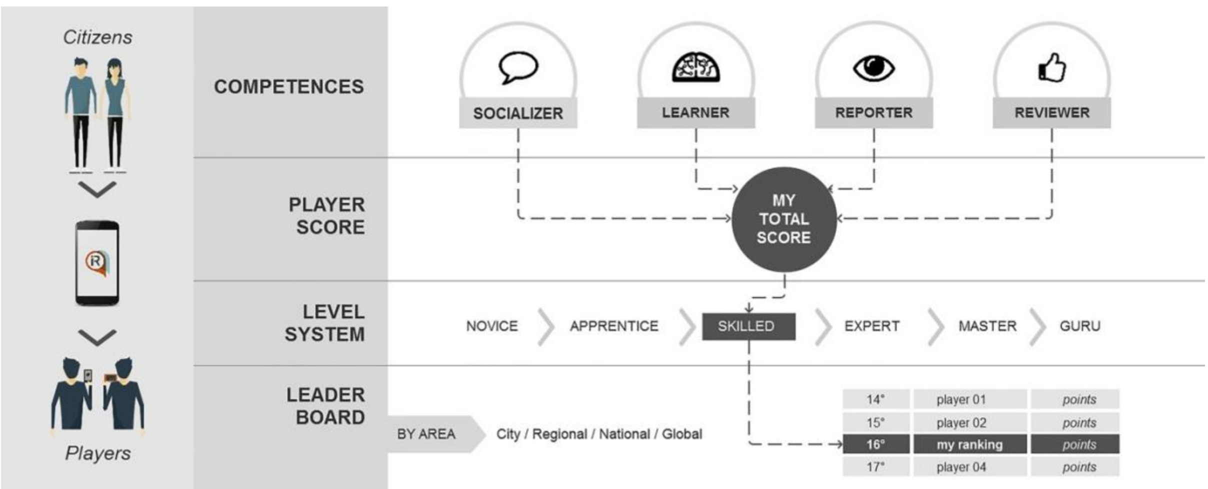
i. Socializer: this competence has been designed to grow the player community. It responds to the relatedness need and entails very simple actions that does not require domain expertise, i.e., inviting friends to join the community and sharing information. For this reason, we enable such actions at all levels.

ii. Learner: users are invited to build up their knowledge on environment and natural hazards both in a "passive" way (e.g., by reading tips), as well in "active" mode (e.g., by answering to quizzes). From the crowdsourcing perspective this phase is relevant to introduce and train users to produce good quality data.

iii. Reporter: this competence allows users to provide data from the field, and it is at the core of the crowdsourcing system. Also in this case, we foresee two modes to stimulate users, who are allowed both to spontaneously send reports, as well as to answer to specific request from the system (created by Spectators).

iv. Reviewer: in order to be included in the DRM and used by emergency managers, reports have to be accurate. For this, reason, reviewer is the highest competence with respect to the level system. Users that have been good reporters can become reviewers and peer-review reports done by other players by upvoting (confirm) or downvoting (reject) them. On top of this level, there is only the Authority validation, which is a necessary step to consider the information fully reliable for DRM professionals.

Figure 7 - Goals, Competences and Users Activities of the



The actors of this gamification activity are involved by means of a mobile application that is used by all users. Each user, based on his/her competence/level, can perform a specific set of activities, which are evaluated by reviewers (see Figure 7). Based on the outcome of the evaluation, users achieve rewards.

Since competiveness is important to increase the motivate of people, the application is associated with a leaderboard. Leaderboards are a powerful game mechanic to engage users, since they provide status recognition within the community and a synthetic feedback on the provided contribution. A leaderboard displays a ranking of players, highlighting the best performance in terms of Scores. Nevertheless, depending on what they show, leaderboards can be demotivating. For instance, a top-10 list would not easily host newbie or medium contributors in a huge community of users, making them feel frustrated. Considering the specific domain of DRM, we propose to include geographically based leaderboards because natural hazards and risks are strongly related to the territory. This allows players to select a reference area on a range, scaling from the city level up to regional, national level.

We believe that crowdsourcing will play a crucial role also in the disaster risk management. For this reason in I-REACT we designed a mobile application for supporting crowdsourcing activities. Crowdsourcing can be leveraged to improve DRM processes by allowing citizens to contribute in monitoring and reporting activities, which are of paramount important across the full cycle of the emergency management.

During a set of demos performed around Europe, an initial set of experiments have been performed to validate an initial version of the mobile application implementing the gamification solution. These first tests confirmed the usefulness of citizen engagement for supporting emergency management. All participants, both first responders and citizens, showed a high interest in the exploitation of the application in the disaster risk management domain.

Moreover, more than 1000 users already downloaded from the google playstore the current version of the app, which has been officially launched in the second semester of 2018. The comments of the users confirm that the quizzes of the app allowed them to increase their knowledge about natural hazards and hence their preparedness to natural events. Hence, the proposed app, differently from similar apps, is not only an alert system. It is an app that increases also the knowledge of citizens about natural hazards.

Cost Benefit Analysis

The I-REACT first demo took place in December 2017 in a transboundary and multistakeholders fashion. This was possible through the direct engagement and institutional support of the UNESCO Regional Bureau for Science and Culture in Europe and the International Sava River Basin Commission. They involved their member states representatives which interacted with the Technical partners of I REACT and successfully performed and demonstrate with an infield deployment along the Sava river, organised with the contribution of the Civil Protection of Croatia, how early warning and response can be interfaced. In particular it was tested how different levels of alert derived by real time data provided by the Flood Forecasting Warning System in the Sava may trigger the activation of Civil protection authorities and/or professional volunteers whose capacity was drastically enhanced by I REACT geo-localised real time monitoring and crowdsourcing functions. The latter were extensively tried and operated by all stakeholders sent on field: Hydro-meteorological and water agency specialists, civil protection authorities, professional volunteers, representatives of local authorities from Slovenia, Croatia, BiH, Serbia, Montenegro and Albania. They all managed to work back to back in an interactive fashion in all the disaster phases envisaged by the drill.

In the aftermath of the drill we conducted a cost benefit analysis (CBA) to understand the impact of I-REACT in the Croatia's emergency management system managed by the Croatian Civil Protection. In the following, we will provide a brief introduction of the Croatian Civil Protection System, a quantification of the main costs for the emergency management, recovery and reconstruction, the identification of main benefits brought by I-REACT in the Croatia territory, and the final CBA results.

The Croatian Civil Protection System

Civil Protection is perceived in Croatia in terms of a system of “protection and rescue” and it is the legal responsibility of the Government to ensure its proper functioning and management. The law of Rescue and Protection, which was promulgated in 2004 and came into force in 2005, introduced three levels of Civil Protection organisation:

- Central level (Level 1), which is primarily responsible for coordinating forces and is represented by the National Protection and Rescue Directorate - NPRD

- County level (Level 2), which is the responsibility of county prefects. In detail, Croatia is divided in 20 counties and the capital city of Zagreb, which has the authority and legal status of both a county and a city (separate from the surrounding Zagreb County)
- Town or municipality level (Level 3), which is the responsibility of the town or municipality mayors. As of 2015, The counties are subdivided into 128 cities and 428 (mostly rural) municipalities.

The National Protection and Rescue Directorate (NPRD) coordinates a protection and rescue system that includes legal representatives, executive and representative bodies of local and regional self-government, governmental bodies such as the National Meteorological and Hydrological Service, and protection and rescue operational forces. It is worth noting that although the NPRD is an independent organisation, it is represented in the Government by the Ministry of Interior. According to the protection and rescue legislation, the basic tasks of the NPRD are risk and vulnerability assessment, drafting measures aimed at preventing crises and accidents, ensuring that these measures are implemented, and effective emergency management in case of major disasters. To better achieve such tasks, the NPRD is structured and organised into various entities at national and at county level.

The central national administration consists of the Directors Cabinet, International Cooperation Department and the Internal Affairs Department as well as five sectors: Civil Protection Sector, Fire Fighting Sector, Sector for 112 System, Fire Fighting and Protection and Rescue School and Personnel, Legal and Finance Sector.

The functionality of the NPRD is ensured through its territorial organization. In fact, each County has a County Protection and Rescue Office – CPRO consisting of Prevention, Planning and Supervision Department and the County 112 center. In the County Offices of the four biggest Croatian cities, there are Protection and Rescue Departments, while in the County Offices on the coast there are also State Intervention Units.

The key dimension considered in Croatia for this analysis is the local one (e.g. Counties). In this context, the NPRD and its network of departments i.e. County Protection and Rescue Offices - CPRO at county level are key actors, considering that four Counties are some of the most critical areas in Croatia, i.e., Vukovar-Syrmia, Požega-Slavonia, Sisak-Moslavina, Brod-Posavina.

Overall, the NPRD is composed by 600 resources at national level and 40 at county level directly actively involved in emergency management, devoting c. 6 hours per week to reporting activities.

Last, but not least, the NPRD has a large network of volunteers, as there is a great tradition in Croatia of volunteering. Indeed, just in 2008, the volunteers represent over 2% of the active population mostly concentrated in inland areas of the Country. This confirms the overall effort of the Croatian people to contribute at all levels to emergency management in view of the collective interest to prevent disasters and reduce human losses.

Main cost items

Starting from the overall flood emergency management process, it is composed by four main activities: preparedness, response, recovery and mitigation. The overall budget dedicated to all these activities can be very high in those countries affected by frequent disasters. With regards to Croatia, costs for emergency management are significant. In fact, c. € 200 million are spent in terms of annual operations and maintenance costs. In particular, the expenditure for tools operating in the Control room (e.g. GIS/risk map services) used to support the activities, in the frame of emergency management is around €2 million, just for the tool, while c. € 1,5 million are spent for licences and subscriptions services. Moreover, the amount of trainings is consistent. Every year each employee devotes from 5 to 10 days of training including exercise on field.

These are only costs for emergency services. In addition to them, damages caused by the disasters should be considered to have a complete picture of costs supported by the whole area. In particular, thanks to the stakeholder involved, an overview of the main damages caused by a concrete case can be presented. The case is related to May 2014 floods in the Sava River basin. During this event the major damages where registered in Eastern Croatia, alongside the Sava' affluent rivers streams. The overall flood had an economic impact of c. €230 million, just in Croatia. Table 1 reports the main types of damages, their impacts and costs. Matching the content of Table 1 with the I-REACT Business Plan, where befits coming from I-REACT adoption have been identified, it can be concluded that the proposed solution could bring benefits in relation to each type of damages assessed. Moreover, an additional impact could be expected in relation to damages that are usually difficult to measure such as for environmental degradation or cultural heritage devastation. Both these damages are not currently available for Croatia, but the I-REACT impact has to be considered. In fact, starting from this damage overview and thanks to the fundamental user and stakeholder support, I-REACT potential benefits have been quantified, according to Croatian peculiarities.

Type of damage	Description	Cost for May 2014 flood
Cost for emergency management	Costs sustained by the CPROs to cope with the emergency	c. €24 million
Affected people	Injured, homeless and affected population	13,000
Death tool	Total casualties	2
Infrastructure damages	Damages to irrigation, drainage, flood protection, transport, water supply and energy	c. €30 million
Damages to productive sectors	Costs for land use and agriculture	c. €8 million
Damages to social sectors	Damages to housing and buildings dedicated to education	c. €160 million

Table 1 Floods main impact in Croatia

Main benefit items

In the following, we analyze the main benefit items related to the use of I-REACT in Croatia. In Croatia, first of all, I-REACT could allow the CPROs to have access to current cutting-edge technologies, which will not become obsolete in the near future. Moreover, I-REACT could bring key benefits to users, in terms more reliable information to use during the disaster, to analyse for future trends and definition of preventive actions.

In

Table 2, I-REACT potential impact has been outlined for Croatia, in terms of percentages of reduction of a specific cost/ damage thanks to I-REACT adoption, according to the NPRD inputs received during the interview process.

	Benefit	Description	Value
Focus of CBA	Reduction of affected people	Reduction of injured, homeless and affected population	8%
	Reduction of death toll	Reduction of total deaths	8%
	Reduction of costs for emergency management	An improvement in emergency management process will cause a reduction of its costs, mainly thanks to information from users and I-REACT interactive components	8%
	Reduction of infrastructure damages	Reduction of damages related to irrigation, drainage, flood protection, transport, water supply and energy	4%
	Reduction of damages to productive sectors	Reduction of costs for productive activities, such as land use and agriculture	4%
	Reduction of damages to social sectors	Reduction of damages to housing or buildings dedicated to education	4%
Only estimated but not considered in CBA	Reduction of environmental damages	Reduction of damages caused to environment, such as destruction of wetland areas and reduction of biodiversity	4%
	Reduction of damages to cultural heritage	Reduction of damages caused to country's cultural assets and properties	4%

Table 2 Preliminary estimation of benefits brought by I-REACT project

As presented in

Table 2, the CBA has a precise focus, in line with the primary direct damages and the available information. In relation to secondary or more intangible costs, no data can be used or leveraged at the moment and estimations could be not reliable, providing not correct findings on these specific issues. For this reason, even if a potential I-REACT impact has been presented, they are not part of the following CBA that aims at providing outputs as realistic as possible.

Final outputs of the Cost-Benefit Analysis

The assumptions reported in Table 3 were considered to run the CBA.

Key items	**Key figures**	
Geography considered	Croatia	
Professional users addressed	4 CPROs in critical areas in the country	
Timeframe and flood considered	May 2014 flood	
Costs/ damages considered	Costs/ damages available and quantified in paragraph **Error! Reference source not found.**. The toll to be borne by NPRD for each affected person is c.€17,700	
Benefit value	% of cost reduction as estimated in paragraph 0**Error! Reference source not found.**.	
Target price for CPROs for I-REACT solution	Social Media	€13,900 for the overall system (one-off) + €43,500 for potential extras + €11,500 for service costs
	Reporting	€14,500 for the overall system (one-off) + €22,500 for potential extras + €12,500 for service costs

	EMS	€27,000 for the overall system (one-off) + €70,000 for potential extras + €20,000 for service costs

Table 3 CBA assumptions

The CBA model considers two main types of benefits, the ones brought by I-REACT solution directly to the County Protection and Rescue Offices (CPROs) and those generated more in general for a wider number of stakeholders (e.g. citizens in affected areas, regulators, and society as a whole…). The first benefits are mainly related to emergency management cost reduction, while the second type of benefits includes annual savings in terms of affected people, deaths and other economic and social damages.

These benefits have been analysed as potential impacts brought by the solution in the May 2014 flood. The “business case” created is a simulation, assuming a solution adoption in most affected areas in Croatia and an apps download and a medium/high usage by of population in these geographies.

Starting with benefits brought to the end-users, it can be said that in case of I-REACT adoption, CPROs could have been saved c. €1,8 mln in terms of emergency management costs, so a few amounts in relation to the overall expense. On the other hand, the situation is quite different looking at benefits for more general stakeholders that are much higher, considering the I-REACT focus and the relevant costs sustained by the country. For example, the reduction of costs for affected people could have brought benefits to the Croatian government and population for c. €17.3 mln in May 2014 flood (considering the possibility to reduce 8% the number of injured, affected and homeless people and a cost of c. €17,700 for each affected person). Moreover, a significant benefit cannot be estimated for the reduction of number of deaths and related costs in terms of value of statistical life. However, in May 2014 two people died, so an additional cost should be considered.

To add on this, c. €30 mln for infrastructure damages related to floods have been registered in Croatia during the May 2014 flood. Starting from this information, a benefit of c. €1.1 mln could have been reached in terms of lower amount of damages in this domain. Also, considering the respective amount of damages, c. €280,000 could have been saved in terms of damages to productive sector, primarily for agriculture activities, and c. €5.6 mln to social sector.

In order to obtain all the benefits stated above (for end users and other stakeholders) the costs foreseen to implement the I-REACT solution in the four most affected Counties c. €171,200 for I-REACT Social Media, c. €126,000 for I-REACT Reporting and c. €636,000 for I-REACT EMS. They include costs for system and a yearly fee for services for each of the foreseen services.

Comparing benefits and costs, the analysis shows an overall significant advantage for the country. For May 2014 floods, c. €26.1 mln could have been saved if I-REACT Social Media was in use, c. €. €26.1 mln if I-REACT Reporting was in place, and €25.6 mln if I-REACT EMS was deployed. These final benefits are composed mainly by a key impact on costs for affected people. This finding reveals the social nature of I-REACT project. In fact, it promotes a solution with an important public utility, without overlooking the commercial aspects and the potential interest coming from the market, as the key insights on Business Plan revealed.

Cost Due to climate change, floods, wildfires and other extreme weather events are becoming more frequent and intense. This scenario poses a challenge for current risk management systems. In the past, data needs were addressed on an ad hoc basis, which included collecting the information at the time of the emergency. However, there is a growing understanding that data collection, analysis, and management can help both short and long-term development goals and support to identify and address disaster risks.

Conclusions

Due to climate change, floods, wildfires and other extreme weather events are becoming more frequent and intense. This scenario poses a challenge for current risk management systems. In the past, data needs were addressed on an ad hoc basis, which included collecting the information at the time of emergency. However, there is a growing understanding that data collection, analysis, and management can help both short and long-term development goals and support to identify and address disaster risks.

A consortium of European and international partners leveraged on their comparative advantages, by teaming up together within the I-REACT project. The project have developed, tested and delivered a solution through the integration and modelling of data coming from multiple sources: European monitoring systems, earth observations, historical information and weather forecasts. All these were combined with data gathered by new technological developments created by I-REACT such as a mobile application and a social media analysis tool to account for real-time crowdsourced information, wearables to improve positioning, as well as augmented reality glasses to facilitate reporting and information visualisation by first responders.

A gamification approach specifically designed for disaster risk reduction is largely used within I-REACT to increase citizens' awareness, foster engagement and create a reputation system within the platform that can facilitate the validation of citizen generated contents. With this approach, I-REACT is able to empower stakeholders in the prevention and management of disasters. Citizens are involved in reporting first-hand information, policymakers are supported in the decision-making process, and first responders are equipped with essential tools for early warning and response.

At the same time, private companies could leverage specific set of I-REACT components to improve their business, when linked to disaster management.

In this paper, we described the architecture of I-REACT and we analyzed in details the components based on social media data, crowdsourcing and gamification. We believe that citizen involvement is crucial to design novel and more effective risk management systems, which are needed to face the increasing number of natural hazards around the world. We also reported the results of a Cost-benefit analysis to describe the potential benefits given by I-REACT.

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