The Design of a Mobile Application for Crowdsourcing in Disaster Risk Reduction

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ABSTRACT

Disaster Risk Reduction is a complex field in which a huge amount of data is collected and processed every day in order to plan and run preparedness and response actions, which are required to get ready and to effectively respond to natural disasters when they strike. This paper, which targets a wide audience, focuses on the design of a mobile application that aims to integrate the crowdsourcing paradigm in current Disaster Risk Reduction processes. The design process is integrated in the User Centred Approach, which we apply through a co-design methodology involving end-users, iterative prototyping and development phases, and five in-field evaluations of the implemented solution. We describe both the design activities and the results obtained from end-users' feedbacks focusing on the perspective of first responders.

Keywords

Disaster Risk Reduction, Crowdsourcing, User Centred Design, Mobile Interface Design, Usability evaluation.

INTRODUCTION

The higher frequency and severity of natural hazards is increasing the complexity of all prevention and management activities. The whole set of methods, practices and activities aimed at preventing and reducing the impact of disaster, as well as managing their residual risks are referred as Disaster Risk Management and Reduction (DRR). DRR practices aim to reduce disaster risks also through a systematic data collection and analysis on disasters causal factors, which are used to orient a wise management of environmental and local resources so as to improve preparedness and response capabilities to future adverse events (UNISDR, 2009). DRR processes involve several organizations at various administrative and operational levels, each of which is equipped with specific ICT systems and services that serve different strategies and procedures. This implies a high complexity, also because local operational procedures vary a lot across administrative regions.

In this scenario, heterogeneous data are considered core enablers throughout all phases and functions of the DRR (Vieweg et al., 2010). The introduction of new ICT solutions able to collect and fuse data from multiple sources can have a positive impact on current operations and procedures, which could benefit from an improved data integration and management. Actionable data sources include remote sensed imagery, forecast models, environmental sensor networks, social media, and also novel mobile applications. In particular, social media platforms such as Twitter and Facebook are commonly used by citizens to collect and share unstructured information about incoming or ongoing crises. This represents a valuable opportunity for authoritative organizations, which could integrate such data into current DRR processes. Nevertheless, the cost to systematize, clean, sort and filter such unstructured and unreliable information flow makes the integration of crowdsourced data a very difficult task.

In this work we tackle this challenge, presenting the design of a novel mobile application (app) designed for integrating a crowdsourced data collection and validation activity into DRR procedures. The design process is integrated in the User Centred Approach, which we apply through a co-design methodology involving end-users, iterative prototyping and development phases, and five in-field evaluations of the implemented solution.

Even though the app targets a wide audience, including citizens, this paper describes the design and the implementation of features dedicated to First Responders[1].

This paper is organized as follows. First, we review related works about the interplay between DRR and ICT solutions, focusing on the crowdsourcing approach and on the user centred/co-design frameworks. Next, we detail the overall methodology we followed and we briefly summarize the results from the co-design activities (Nguyen et al. 2017). Then, we describe the app design and we evaluate the usability of the implemented solution from ad hoc questionnaires. Finally, we present the conclusions and future works.

RELATED WORKS

During incoming and ongoing hazards, citizens generate and exchange a big amount of information. If properly filtered and processed, such data represent a great value that can enhance the situational awareness of both operation managers and first responders acting in the field. The most recent DRR approaches invite to take advantage of the direct participation of citizens (Abbasi et al., 2010). In critical conditions, people need to seek and share information, primarily to stay in contact with their family and community. Mobile technologies allow the fulfilment of these needs and can support the application of crowdsourcing approaches. Information access and sharing are two core features of the crowdsourcing, which is nowadays a consolidated socio-technical paradigm that mainly leverages on: (i) the willingness of people to actively contribute to actions of mutual interest (De Albuquerque, 2016) and (ii) the availability of current technology where services and applications running on mobile devices are able to gather and exchange geo-located information about a crisis (Kanhere, 2011; Littledyke, 2008).
The combination of social needs and technological capabilities allows the crowdsourcing to bring in-field data from the local up to the organizational level. Nevertheless, it exhibits some critical aspects. One of the most important issues is the information reliability, because crowdsourced data can be affected by from disinformation, false judgments, social biases (Guo et al., 2104; Ganti et al., 2011). Other relevant issues are data accuracy, sampling, temporal coverage and precise geo-localization, all of which are crucial for integrating crowdsourced data into DRR procedures. The ability of contributors to produce accurate data is considered a key aspect for applications supporting the environmental surveillance and the natural hazard prevention (De Longueville et al., 2010). Validation techniques are required to guarantee the reliability of the data collected from the crowd. They can leverage on automatic systems based on Artificial Intelligence as well as on human approaches where experts and/or peers have to manually perform the validation. Both approaches can benefit from the integration of reputation systems that dynamically rate contributors (Pennachiotti, 2011). Finally, crowdsourced data require tailored visualization techniques as well as specific skills for data analysis and interpretation within emergency organizations willing to include them in their procedures.

A mobile application for crowdsourcing data collection and validation activities within DRR operations shall be envisaged as a tool enabling new forms of cooperation between local agencies and citizens without disrupting existing procedures. The knowledge of the operational context, of the end-user organization and procedures is essential for the mobile application design, which must define functionalities, interactions and interface characteristics. A deep knowledge of the destination context and an exhaustive understanding of the end-users needs, skills, culture, and context are core concepts of the User-Centred Design (UCD) approach (Norman et al., 1986). The UCD is a methodology that entails several tools and techniques to systematically collect and use qualitative and quantitative data, which are used throughout the design and development process. Among the UCD methods, *the participatory design (or co-design)* focuses on collaborative practices that actively involve stakeholders and end-users onto the design challenge. Note that the co-design implementation requires a careful planning and a wide understanding of target domain. In co-design method, participants are considered as designers (Stepanek, 2015), stimulating the dialogue on a common problem and on possible solutions that can evolve in prototypes or shared artefacts. Through dedicated techniques, the co-design allows non-designers to articulate design proposals as a useful starting point for further professional developments (Sanders et al., 2010). The collaborative design activities allow to widen the design team's vision and develop a situated knowledge of complex domains. Moreover, the engagement of end-users helps in the design of usable (effective, efficient and satisfying) solutions.

We consider all the aforementioned issues to design and implement a novel app for crowdsourcing data collection and validation activities for DRR.

[1] The features specifically dedicated to citizens are presented in our previous paper (Frisiello et al. 2017).

METHODOLOGY

In order to collect a deep knowledge of the user needs and to set the context of in-field data collection activities, we followed the co-design methodology described in (Nguyen et al., 2017) involving representatives of the DRR ecosystem, namely emergency operation managers, field agents, volunteers and domain experts. The co-design process included: (i) an online survey aimed to map the expertise, interests and needs of the participants; (ii) an intensive co-design workshop (two full days) supported by a dedicated toolkit that has been designed to guide the workshop activities and at the same time to systematically collect information; (iii) the analysis of the data collected to extract end-user requirements for the mobile app design and development. Both functional and non-functional end-users' requirements have been derived from co-design workshop, while the information collected on the organizational level has provided relevant hints to define the user's profiles to be implemented in the app and the related permissions in compliance with the real processes and roles. Finally, the specifications on the content architecture (functions and information) and the interaction patterns have been defined, and then prototyped at levels of fidelity, first wireframes and then mock-ups. The mock-ups have been created using as much as possible elements from the Material UI library, which contains a large set of UI components ready to use and already familiar to end-users because commonly adopted in all views of the Android system

The participatory approach has been applied along the whole process, including the user evaluation activities. In order to validate intermediate versions of the mobile app, five demonstrations and user feedback sessions have been conducted in five different countries (Croatia, Italy, UK, Spain, Finland) involving end-users in real context. The evaluation procedure applied is hybrid: it combines the data collection from in-device usage in real context and from post-task surveys via: (i) the System Usability Scale (SUS) (Brooke, 1996) to evaluate usability, regardless of the different stages of maturity of the solution (Muddimer, 2012); (ii) the Net Promoter Score (NPS) as indicator of the perceived maturity of the solution on the base of a ten-score scale (Reichheld, 2003); (iii) a set of ad-hoc questions to investigate specific aspects of the app, such as the visualization layout, readability, procedures sequences.

CO-DESIGN RESULTS

The co-design workshop provided detailed indications about the types of data needed in each DRR phase, the expected flow of information and the applicable roles and related permissions, as well as on the information flows and graphic user interface (GUI) (Linux Information Project, 2004) design. It resulted that the crowdsourcing is positively seen as an opportunity to integrate data from the field and to improve the environmental surveillance. This capability is considered particularly useful during the response phase, in which contextual data can provide a deeper situational awareness of hazardous factors and can support decision-making processes. Hazard related data, together with indications of damaged infrastructures and resources availability, are the most relevant ones. Additionally, the provided information must be linked with the identification of the reporter, i.e., the person who provided the information, whom should be classified according to its role (e.g. citizen, professional in order to acknowledge reliable data. It resulted that volunteers are considered as trustable as a professional, while citizens cannot be equally considered. These considerations have been taken into account in the app design to create a role-based role visualization and to differentiate the data collection as well the validation procedures.

The visual prototypes produced highlighted two equally important information flows: an informative data flow, from the system to the mobile app, and a generative data flow, from the app to the system. The first flow is initiated by the authorities and includes: (i) alerts to the field, (ii) geolocated data (e.g. hazard and risk forecasts). The second flow is centred on the crowdsourced data generated in the field via mobile devices and geographically shared with the neighbouring community as well as with control centres managed by the authorities. These capabilities bridge a gap between Decision Makers sitting at control room sand in-field agents.

The co-designed artefacts suggesting an almost univocal content architecture, which we translated into a visual layout placing the authoritative informative level on the upper part of the screen and the crowdsourcing functionalities in the lower section. Furthermore, we translated the data collected in high-level guidelines for the app design, namely modularity, context-sensitiveness and reliability. They are defined as follows:

- *Modularity*: the DRR processes includes several processes, scenarios and target users. The key approach to handle this level of complexity is the modularity, i.e., the possibility to selectively provide and activate functionalities to different organizations. By avoiding the ‘one solution for all’ approach, a crowdsourcing solution can be integrated within existing systems and regulations.
- *Context sensitiveness:* the co-design phase showed that understanding the context is a top priority for emergency organizations, especially in the Response phase. First responders expect a context awareness tool able to support field operations providing additional data. They consider reliable the data coming from the system and, at the same time, they are willing to send data back from the field. This bidirectional

communication flow can enhance the effectiveness of in-field operations, especially when tight time constraints exacerbates stress condition.

- *Reliability*: trustworthiness is key to establish an effective data exchange. Therefore, the data produced by the crowd must be validated in order to be accountable. This requires a specific and distributed validation tasks to be designed within the mobile app. Interestingly, participants indicated that data sorting would let to quick spot relevant information, easing the validation task.

All these guidelines have been fully considered in the design of the mobile app.

THE MOBILE APP DESIGN AND PROTOTYPING

In this section we describe the design of the app[2], which we organize in paragraphs following a top down approach, starting from the *Access* (login and home screen) and then detailing the main informative sections. First, we explain the *Map & Forecast* section, which visualizes map *Layers* and other *location-based contents* on the map, then we describe the *Communication* and the *Social Media* sections, which shows the communications from authorities (*Warnings* and *Report Requests)* and the content extracted from Twitter, respectively. *Report Requests* allows authorities to request a targeted in-field data collection activity from app users, selected by their role. Finally, we present the *reporting* (*Do Report*) and the *validation* procedures. In each paragraph we include both the textual description and the corresponding visual representation of the explained functionalities. *Technical choices.*

Access: to use the app, an active account is required. Professional users are assigned to a given organization units and can have several roles among: 'Decision Maker' (people working in the control room), 'Organization Responsible' (the responsible of the organization with respect to the app) and 'In-field agent' (people operating in the field). The Home (**Figure 1**, right), which appears after the Login (**Figure 1**, left), allows to access the main app informative sections, which are placed in the upper half of the screen, namely: '*Map & Forecast'*, '*Communications*', '*Review'* and '*Social'*. In the lower half there are two other sections, namely '*Settings'* and '*Help'*. The 'Settings' section allows to set user preferences about the language, the base map style, the *time window* and a *distance* in kilometers. Note that all information in the app are retrieved according to a given temporal interval, identified by the *time window*, and to a geographical area, i.e. the Area Of Interest (AOI), which is computed as the bounding box that inscribes the circle having as center the user position and as radius the *distance* specified by the user. The 'Help' section provides supports for newcomers, presenting a quick tour of the app. Finally, the bottom area is dedicated to specific call-to-action buttons: the 'Do Report' and the 'Report Request'. Their procedures are described in the '*Do Report'* and *'Report Request'* subparagraphs.

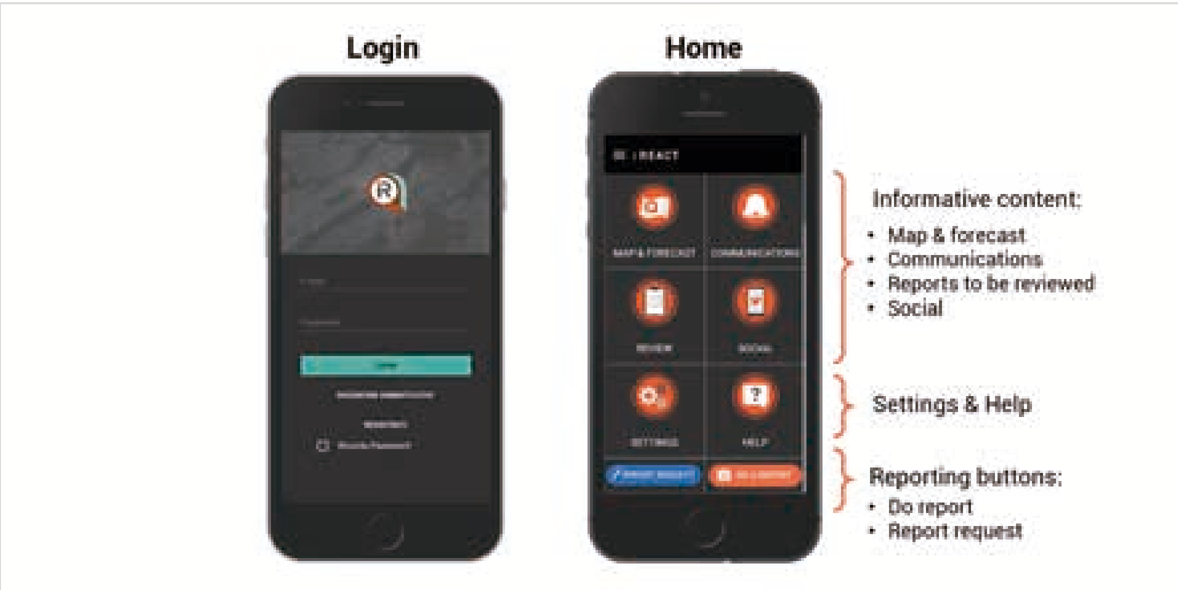

Figure 1 - Login (left) and Home (right) of the app.

Map & Forecast: location-based contents are made available in two different views: on the Map as color-coded pins and on a list-view. The Map enables a georeferenced overview of the current situation within the user's AOI.

[2] The app is named I-REACT

Every content available in the app (both incoming and outgoing information) is geo-localized and includes either a timestamp or a validity period. On the Map view, the user can pan and zoom the map. As the zoom level increases (zoom out) the pins are clustered in circles, where the center of the circles shows the number of the clustered elements and the circumference is proportionally colored according to the types of the clustered elements. The user can also click on a pin/pin cluster. If a pin is clicked, the map is centered on that pin and its informative card, which provides essential information about the pin, appears in the top part of the map. To access the full detail (Detail view) of a location-based content, the use must click on its card. If a pin cluster is clicked, the map is zoomed to that cluster until the cluster breaks into its sub-elements, which can be single pins or other clusters. This is a standard behavior and it is available in many other apps. In compliance with the co-design outputs, the main map controls are placed in the screen area reachable with the thumb (bottom part of the screen), which is known to be the most accessible (Hoober and Berkman, 2011). The bottom right controls let to center the map on the user position and start the report-creation procedure, while the left control lets the user to select the map layer to be visualized. A 'Compass' place in the top right portion of the map completes the set of controls. (Figure 2)

Given the very large amount of information potentially available on the app, the Map shows data solely on the user AOI (dotted line) and within the time window (showed in the green bar). In the app, all the spatiotemporal filters are editable from the Settings at any time.

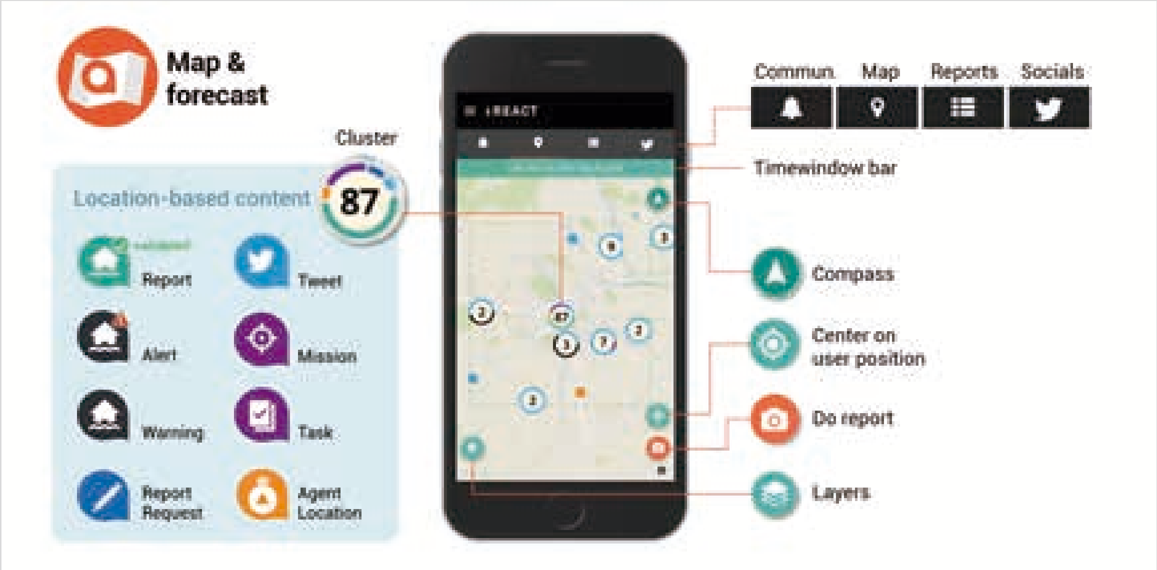

Figure 2 –Map & Forecast view: location-based contents visualized on the map together with map controls.

Layers. From the 'Layer' the user can select a map layer to be visualized on the map, one at a time. The detailed list of map layers available in the app, e.g. meteorological forecasts, is omitted for brevity. When a layer is activated, the app visualizes it on the map, enabling also the Legend button and the Player widget. The former allows to show the legend of the layer containing the association between the color and the values/classes of the layer data, while the latter enables the visualization of the temporal of the evolution of the selected layer, if any (Figure 3 shows an example of a temperature forecast). From the Player widget it is also possible to read the layer metadata.

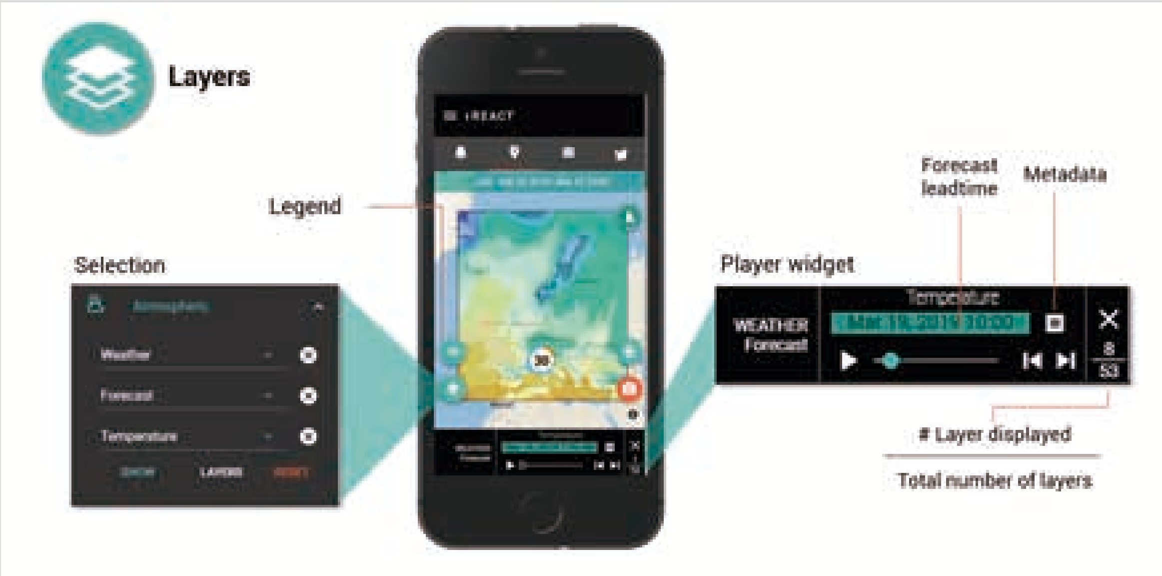

Figure 3 – Map view of a forecast layer (temperature): Layer selection (left), map view (center), player widget (right).

Communications: messages regarding Warnings (Alerts) and Report Requests coming from an authority or other trustable source (e.g. weather bulletins from regional/national authorities) are shown in this section (**Figure 4**). Warnings comply with the Common Alerting Protocol (CAP) (Standard, O. A. S. I. S., 2010), which is a standard format enabling the interoperability and the integration of alerts coming from different sources. Note that report requests are received by the in-field agents according to their location and the AOI specified by the sender. The request accomplishment is not mandatory, while the report request creation procedure is simplified as much as possible by a pre-selection of the requested parameters. The Communciation List view is omitted from brevity as it is very similar to the Report List views shown in **Figure 5** and **Figure 7**.

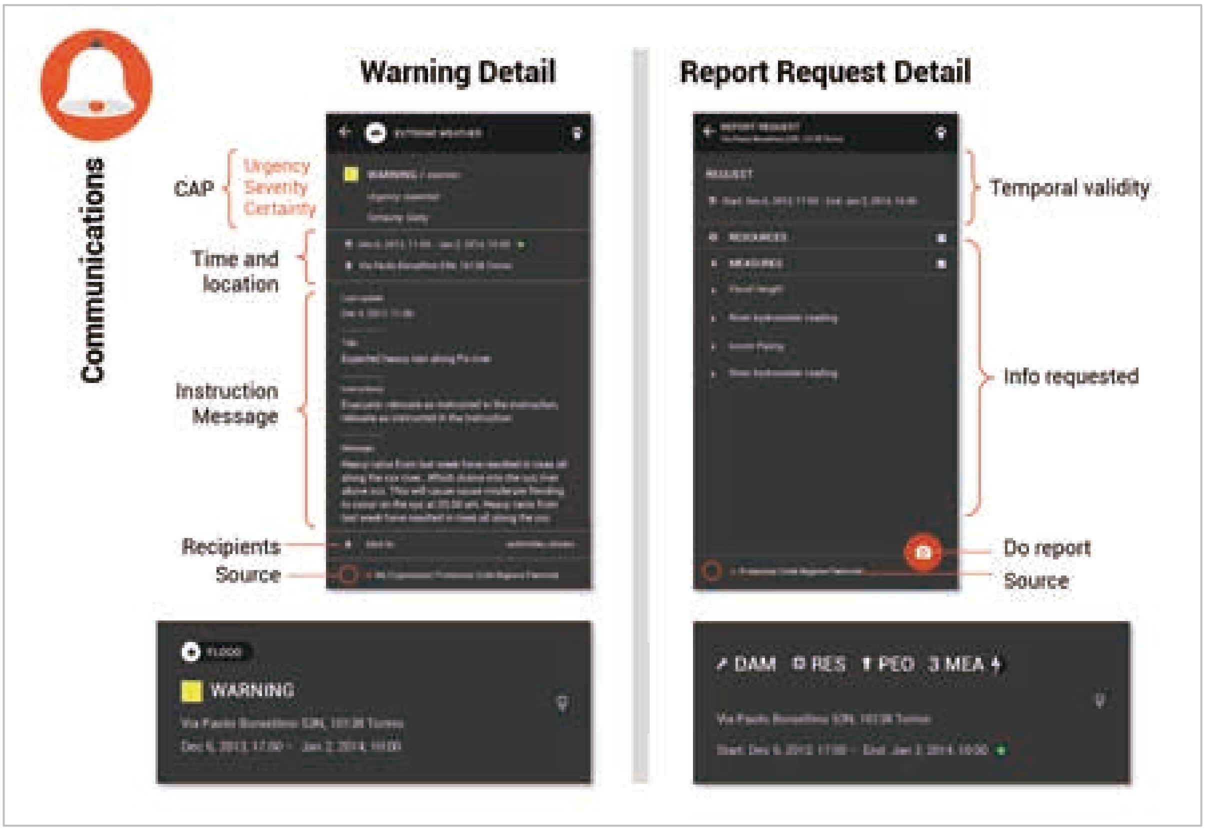

Figure 4 - 'Warning' (left) and 'Report Request' (right): card (bottom) and Detail (top) elements.

Social Media: this view displays automatically extracted hazard-related Tweets according to the user selection (**Figure 5**). The algorithm to extract and classify hazard related tweets is outside the scopes of this paper and it is detailed in Rossi et al. 2018. In the List view, quick filters allow to select the language, the time range, and the time sorting. Each extracted Tweets is also automatically classified with a set of labels, and the app allows users to give feedbacks in order to confirm or modify the automatic classification, which is structured into: named locations, hazards, information type (Affected Individuals, Caution and Advice, Donations, Emotional Support, Infrastructures, Volunteering), Informativeness (yes /no values), Panic (yes /no values). When Tweets are edited by a Professional, his/her feedback is considered as a validation, and the assigned labels are visible to all users, including citizens. If the feedback is given by a citizen, the system records it without propagating the user classification to other users. After a validation, no further amendments are allowed. All feedbacks contribute to iteratively improve the accuracy of the classification algorithm.

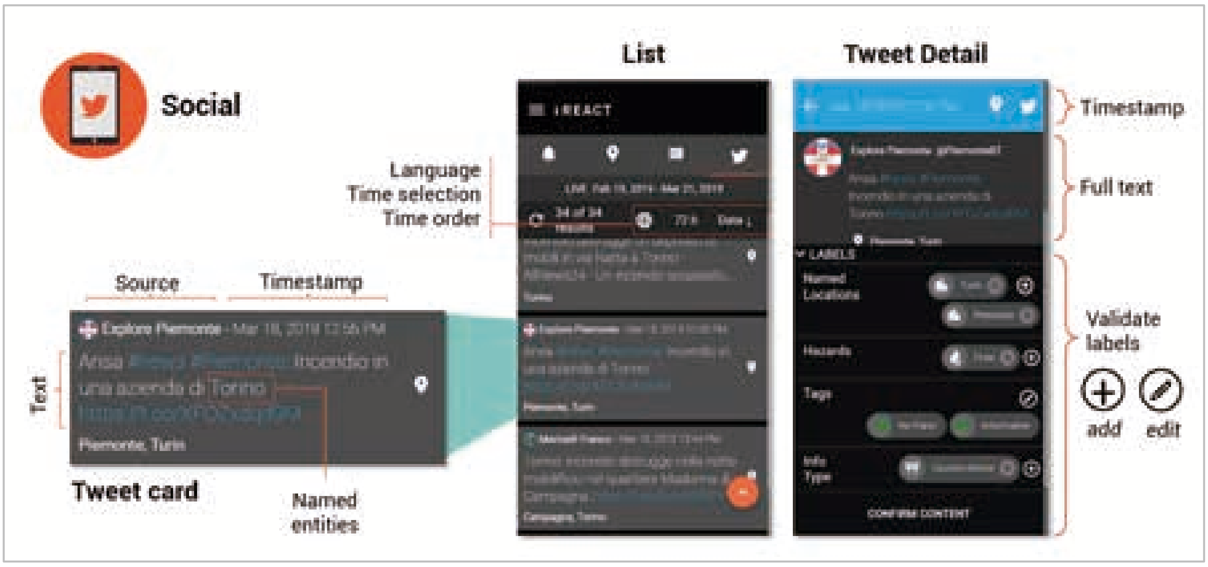

Figure 5 – Social media information: Tweet card (left), List (center) and Detail (right).

'Do Report' and report validation: being the collection of data from the field (Reports) the main activity supported by the app, the Do Report call-to-action has been included both in the Home and in the Map View. The report creation is a guided procedure in five steps: 1. Picture capturing; 2. Geo-localization; 3. Hazard description; 4. Information category; 5. Information details (**Figure 6**). The structured sequence replies to the need of having a pre-categorized and systematic data collection, and of minimizing typing errors, which are very common when free text inputs are used. The reporting procedure starts from the photo, since it has been indicated by organizations as the best format to quickly understand the situation described. Then, the geo-localization is acquired either through the device position (GPS) or with a manual selection of a point in the map. The latter possibility has been added to allow the reporter to stay at a safety distance from the hazardous point while doing the Report. A Report can include both quantitative and qualitative measures, which has been mapped using standard scales (e.g. Beaufort scale for wind velocity) when possible. The report form presents dynamically the set of measurement suitable according to the selected hazard, if any. Besides 'Measurements' it is also possible to report the presence of 'Damages', 'Resources' or 'People' by a multiple selection among listed items. These lists have been created after benchmarking multiple categorization across different emergencies organizations since a unique standard is not available and there is a great variability on the base of the hazard (e.g. water can assume opposite value whether there is a flood or a fire). The description of the report information categories is detailed in Frisiello et al. 2017.

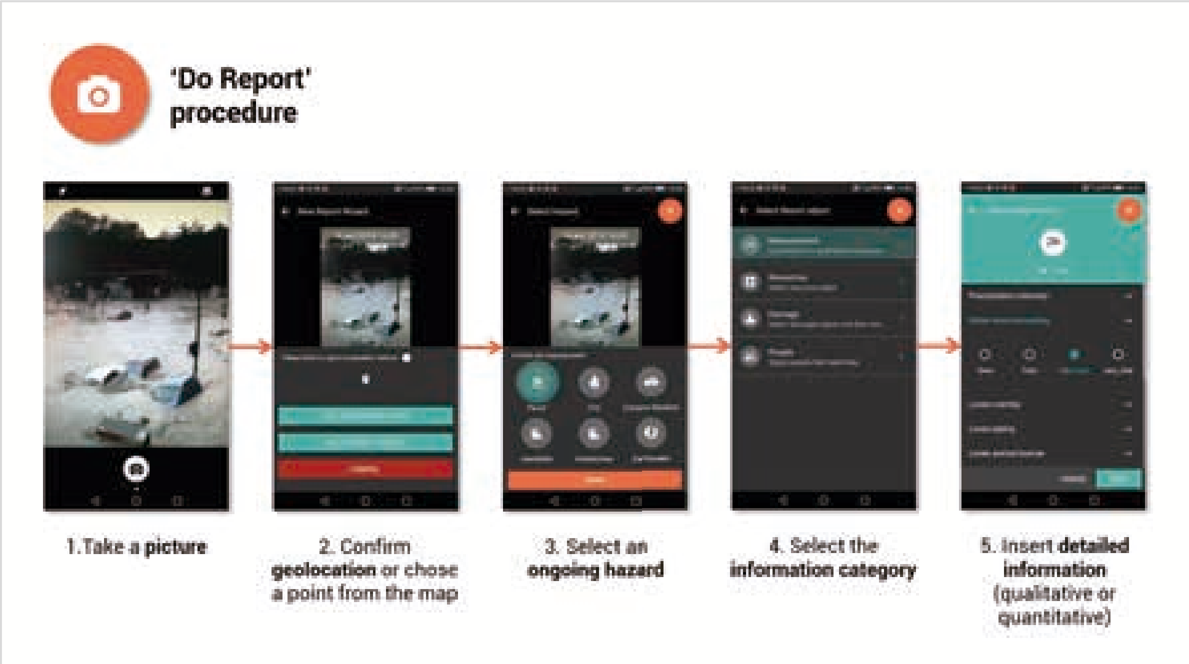

Figure 6 - Report creation procedure made of five different steps.

The report validation works at two different levels: citizens can peer-review other citizen reports by upvoting or downvoting, while specific professional roles, namely 'Decision Makers' and'Organization Responsibles', can validate/reject citizens' reports. All reports formats (Card and Detail) show a counter with upvotes and downvotes received by other citizens in the form of thumbs-up and down icons. The validation of a report is allowed only when consulting the Report Detail since a detailed evaluation is required (**Figure 7**).

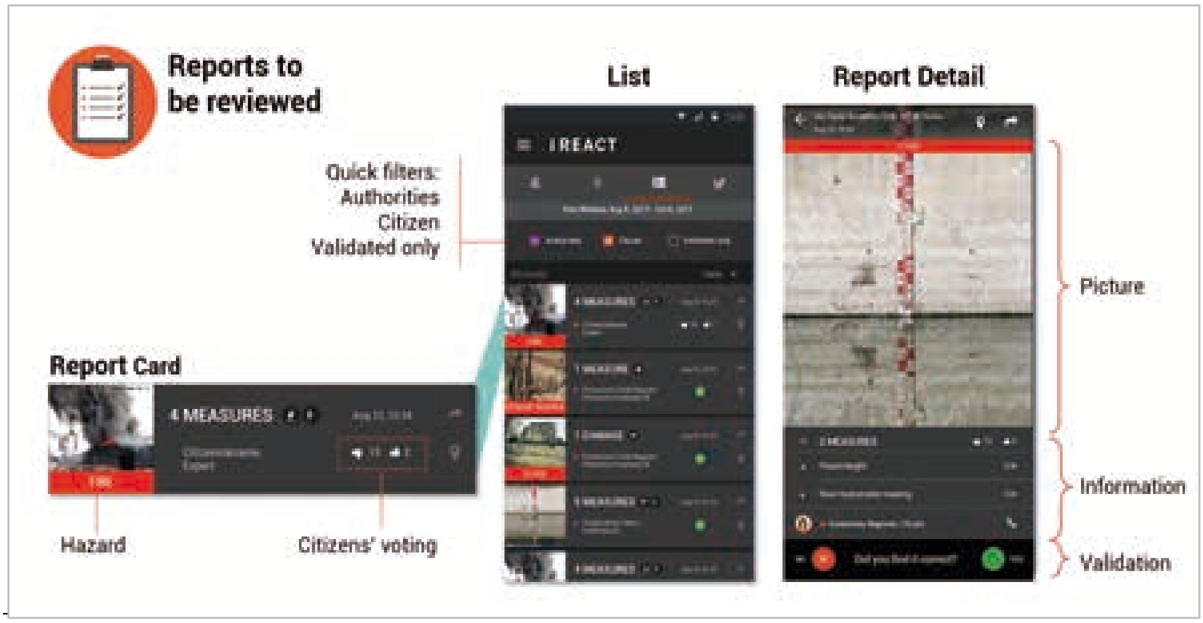

Figure 7 – Reports to be reviewed: Report card (left), List (center), and Report Detail (right).

USERS' EVALUATION RESULTS

The functionalities of the app have been implemented progressively and iterative user tests have been carried out to assess the app usability from the first responder's perspective. Over two-years, four training and simulations sessions in different European Countries (Sava Basin in Croatia, Cataluña in Spain and Helsinki in Finland) and one large scale exercise run by diverse European Civil Protections gathered in Italy have been the stages for the mobile app testing in the field. Realistic flood and fire disaster scenarios have been simulated envisaging the usage of the app, and immediately afterwards a feedback questionnaire was distributed to be filled online or on paper. 51 valid questionnaires have been collected from experts, professionals and volunteers from Public

Administration, emergency and environmental organizations at local, national and European level. The sample composition is heterogeneous per gender (27% female, 69% male, 4% not specified) and age (29% age: 25-35; 55% age: 35-55, and 16% over 56). In the following subchapters, we present the overall evaluation computed through the questionnaire as well as some comments received, which we structure according to the main app functionalities.

Overall evaluation

The overall satisfaction of the users has been computed after through the System Usability Scale (SUS), which has been derived from 10 questions exploring several features, including the ease of use, the experienced difficulty, the acceptance and the appropriateness for the tested app functionalities. The SUS output ranges from 0 (minimum) to 100 (maximum). The app received an average level of satisfaction (average SUS score of 62 in Table 1), which is slightly below the average according to the definition in (Sauro, J., 2011). It must be noted that the SUS is determined by several factors, including the level of a-priori experience, which generally results in an increase of SUS between 6% -15% (Muddimmer et al., 2012).

Table 1 - SUS overall scores

Min	37.5
Max	87.5
Average	62

Analyzing the replies on the single SUS variables, evaluated on a 5-points scale (1 very poor, 5 very good), it is possible to see that the integration of different data is the strength point of the app (Table 2).

Table 2 - SUS average per item

Item	Average
1 intention to use	3.6
2 complexity	2.6
3 easy to use	3.5
4 need of support	2.7
5 integration	3.8
6 inconsistency	2.3
7 desirability	3.4
8 cumbersome use	2.5
9 confidence	3.3
10 learning	2.7

The NPS, asking people to what extent they will recommend the app to others, confirms the positive attitude to use the proposed solution, in line with the SUS variable '1-intention to use'. The overall NPS scores computed across all demonstration is 6.8/10, while the NPS of the SAVA demo (the first one) and of the the Finnish demo (the last one) are 5.3/10 and 8.3/10, respectively. This is linked with the fine-tunings that have been made after each demo in order to improve the usability if the app functionalities. Therefore, most of the participants would recommend the app to other organizations. Some positive comments pointed out the good integration capabilities of the app and the possibility to engage citizens in the emergency procedures. Looking at other indicators, the full list of which is omitted for brevity, it resulted that users consider the app worthy (mean 3.9/5) and innovative (mean 3.5/5). Moreover, the graphic design is particularly appreciated (mean 3.9/5).

Ease of use of the main functionalities

Access. Enter the app results simple, but some crashes have been recorded and some delay was experienced in loading all the system information the first time. Therefore, adjustment have been made to improve performances reducing the bandwidth and memory requirements, e.g. the bounding box has been set to 50 km, which is enough to guarantee a good context awareness.

Navigation. The navigation structure is comprehensive and rich. It was appreciated that many phases of the emergency management cycle have been considered in the app design and in the content structure. Nevertheless, the information and the options presented are still too dense and users suggested some simplifications, e.g. reducing the layers categories and subcategories.

Settings. Time-window setting and layers activation are in general easy, with some negative comments o number of steps required in order to activate a map layer. Although a layer-button is present on the map, its findability is perceived as low. Changing the UI appearance (color and size) should be sufficient to highlight it. A further rationalization of the layer categories could make the selection and activation quicker.

*'Do report' and Report Request***.** Reporting have been tested in all demos in order to stress and evaluate the core functionality of the app. It has the highest success rate (87%) but also the high perception of difficulty (3.7/5) meaning that a training phase is needed to master the process and know the given options. The guided procedure has been appreciated but some comments were raised suggestion a simplified and shortened procedure, especially to target the general public. Another need would be to have a quick report option to send a simple geolocalized picture without content in very time constrained situations.

The *Report Request* works well, and it results very useful, but the scenario of reporting during an ongoing event might suffer the dependency of the system on the Internet connection. This is the weakest point of the app according to many users. The efficiency (effort spent, and number of steps required) is acceptable but it could be improved.

Validation. The procedure to validate reports is easy, it requires just a tap and hold on the proper button. Nevertheless, some details of the GUI could be improved. The used icons, designed to recall commonly known symbols, do not explicit well the specific types of actions available and their consequences. Reading the validation status of reports resulted very easy on both visualizations (map and list views).

Communications (alerts/warnings). The possibility to receive alerts/warnings is very interesting and important for the context of application of the app. Nevertheless, the notification should last longer when the app is in foreground as some comments claimed it disappeared too quickly. It is also difficulty to find the information after the notification. To improve this aspect the notification toast has been made permanent until the user selects one of these possible options: 'Close' to close or 'Ok' to go to the 'Detail' view of the alert/warning.

Social have been the last feature implemented and quite appreciated for context-awareness, with a slight preference for the map visualization that provides a geospatial overview (4.2/5) over the list browsing (3.9/5). The mechanism to provide feedbacks on the Tweet labels resulted not easy to do, but the GUI resulted clear, suggesting that an onboarding process could help to increase the social validation procedure.

In general, the organization of all functionalities have been appreciated with the need of simplification in some points, as the app is very rich in content. Comparing the two main information flows, the incoming data were quite clear to receive while the report creation showed a certain complexity of execution. Although the designed reporting has strutured the information exchange between the Decision Makers and the in-field agents, a certain degree of flexibility must be allowed to cope with emergency scenarios where it is better to have an incomplete report than not having it at all (for example only the picture with timestamp and position).

We observed pros as well as limitations of doing this kind of evaluation through simulated in-field demonstrations. On the one hand, we had the opportunity to test the app in the field and to immediately observe the app usage during a realistic operativity, involving simultaneously multiple users as it would be in a real emergency context. On the other hand, it was not possible to record video of the app usage. Another advantage of the simulated in-field demo is that it also allowed for informal talks with professional end-users. All the feedbacks were kept in the loop during the app fine tuning design, which entailed several revisions and feature improvements.

CONCLUSIONS AND FUTURE WORKS

The implementation of the co-design methodology based on the User-Centred Approach (Nguyen et al., 2017) resulted very effective to define key guidelines for the design of a crowdsourcing mobile solution for DRR scenarios and onboard the end-users from the very early stage of the design process. Regarding the iterative design, implementation and testing approach, we had the opportunity to use the demos to gather feedbacks that allowed to validate along the way the functionalities as they were released, distributing over time the changes and the management of the implementation complexity. The in-field demos confirmed that measures of onboarding were needed (both for professionals and citizens), which has been addressed by the 'Help' view integration in the final app to better explain the app functionalities to beginner users.

The main criticality seems to be the finding of the right balance between structured the procedures included in the the app so as to open the crowdsourcing to wide public while being integrated in existing emergency procedures and systems. This suggests that group of citizens could have been engaged in the co-design together with DRR experts to collect complementary requirements.

Future works will be focused on the full implementation of functionalities for citizens. Among these, a gamification strategy for citizens (described in Frisiello et al. 2017) to increase citizens' awareness on natural hazards through educational contents and to foster citizen engagement is foreseen. The gamification strategy will allow to enroll citizens in structured data collection activities and features a solid validation criterion.

The app is called I-REACT and it is published on both the Android and Apple store. At present (15/02/2019) it counts 4.5k downloads from citizens.

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