IntCris: A tool for enhanced communication and collective decision-making during crises

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ABSTRACT

Responding to a large-scale disaster such as an earthquake or hurricane is a collective problem. Human agents are increasingly collaborating with non-human agents (autonomous systems) in attempt to respond to a disaster. IntCris is a prototype intended to bring together interaction for human and non-human agents to aid the decision-making process by focusing on how to facilitate the "correct information to the correct agent" problem as well as encouraging new and agile behaviour. We focus on three categories of information: command, report and personal with a formal grammar to accompany the implementation. The requirements for the software were inspired by real life case studies from Hurricane Katrina, the Fukoshima Nuclear Disaster and Hurricane Sandy. The contribution of this work is to advance technology that brings together HAS (human and autonomous system interaction), in addition to enhancing collective intelligence.

Keywords

Collaborative technology, emergency response, collective decision-making.

INTRODUCTION

The complexity of large-scale disasters means that different agents need to collaborate in order to respond effectively. Increasingly, this type of collaboration is extending to include non-humans, specifically autonomous systems. Autonomous systems can operate independently of human guidance, thus making their own decisions and determining their own course of action. They are advantageous in that they can be deployed in minutes and can conduct high-stake rescue operations that are too dangerous or even impossible for humans to conduct. In addition to being able to provide physical help to their human counterparts, autonomous systems are increasingly being used in the decision-making process, for example one can consider programs that automatically update stakeholders of current weather conditions or other relevant information. The need for better ICT in emergency response has been highlighted for nearly a decade now (see for instance [Palen and Liu 2007]).

When a disaster occurs, response agencies have command procedures and protocols in place, which they are expected to follow. In order to do so most effectively, it is crucial that the right agents receive the right information at the right time, given that circumstances are uncertain and can change rapidly. Furthermore, it is often the case that non-official agents, i.e. people on the ground or even remotely possess important information that is needed to respond to the emergency as in the case of social media and crowdsourcing. For example, in the 2007 Virginia Tech shootings, the names of the deceased were available online via social networks, before official organisations were able to obtain them (Vieweg et al, 2008). An important aspect of the work we are presenting, is a prototype that makes a contribution towards the problem of providing "the right information to the right agent at the right time" in complex situations where the "right agent" can be a human, UAV or autonomous virtual agent, and where the right information can be provided by both human and non-humans, and a “complex situation” is one observed during emergency response during large-scale disasters. The product of this work is IntCris, a collaborative platform that facilitates gathering and divulgence of information provided by human and autonomous agents in emergencies and large-scale disasters. It is anticipated that access to the information provided by different agents will help to aid collaboration, co-ordination, situation awareness and decision making within these contexts. IntCris operates on mobile devices, which include tablets and smartphones. It is novel in that it incorporates interactions between humans and autonomous systems within these circumstances, in addition it does not focus on a particular point of view, instead it incorporates several different aspects with a focus on collective decision-making and in communication and interaction between several individuals, agencies and coalitions. There are many examples of apps dealing with emergency management, a comprehensive list can be found in (app list 2013). Similar academic work includes (Coughlan et al, 2011) where information gathering divulgence, and deliberation are studied, but in a context of academic learning. Here software is developed to aid collaborative learning in an “Out There and In Here” system. The idea is that there are two groups of students, one learning “on the field” and another “in here” able to take advantage of technology and resources at their disposal to aid in sensemaking and in divulging relevant information. We are unaware of what the “in here” portion of this system would mean for our software, but can hypothesise the possibility of synchronizing IntCris to something akin to the social media command centers we have witnessed so many agencies develop. A pioneering example is given by Red Cross’ social media command center (Fox, 2012), which was followed by several agencies involved in disaster management. The social media usage is no different to what we can witness in most post-disaster management companies and includes responding to requests in real time as well as using social media to understand patterns in what affected communities need. In addition, like many organizations it posts useful information to the public, whether during a crisis or not. Social media considerations are encompassed in our studies by analyzing the sort of communications that happen through social media during a crisis, specifically Hurricane Sandy.

We must mention two more areas of work that are relevant to us; namely collective intelligence (emergent knowledge as direct result of a group collaboration) and group decision making software. Work that attempts to harness collective intelligence can also be compared to ours, since this is in part what we are attempting to do. We wish to enhance interactions between people during crisis, through technology and also to gather information in a way that filters out irrelevant data, by attempting, in a way, to “harness” the collective intelligence of users, allowing them to make better individual and group decisions, so to help those afflicted by a disaster or those attempting to provide relief (officially or unofficially) to help themselves. Several examples of collective intelligence applications can be found in (Gregg, 2010). Technologies that facilitate group decision-making are also relevant, a starting point to understanding literature on those can be found in (Kiesler, 1992). An example is given by MIT’s Collaboratorium (Klein and Iandoli, 2008) developed to facilitate discussion, based on argumentation theory and tested on a community of 220 graduate students, on the topic "the future of biofuels in Italy". Collective intelligence and crowdsourcing have been increasingly studied in an emergency management context; a prominent example is given by Ushahidi (Ushahidi, 2013), an open-source platform which allows crowdsourcing during crises and provides visualization of gathered data as a timeline or map.

Another important feature of our software is to enable better communication mechanisms to those involved in a disaster, and we are certainly not pioneers at this. For instance, in (Rudinsky and Hvannberg, 2013) an interface for communications of first responders and commanders is designed intended to be used during training (via simulations). It shows that significant simplification of communication interfaces can be achieved but that it cannot be simplified into a single unified interface.

During post-disaster relief, information flows (Goggins et al, 2010) from authorities to the public, from the public to authorities and from peer-to-peer. This prototype is focused on peer-to-peer as well as authority to public, but pays less attention at how authorities receive public information. We are not so concerned with how information flows, instead we are interested in information as a necessity for collective decision-making.

WORK PRIOR TO PROTOTYPE

We have conducted an extensive literature review and together with case studies we have created a list of requirements for successful command and control in complex situations; we then used these requirements to create our own implementable formal grammar for command and report (in the style of (Hieb and Schade 2007, 2008)), which can be found bellow.

Report -> To (From) (ReplyRequired) (VisibleBy) (CommandResponseHouseRule)* (CommandResponseUnexpected)* TimeStamp ReportsSameMission* ReportOtherMissions*

Command -> To From StartState EndState Intent (Method) TimeFrame OtherCommandsMission*

OtherCommandsOtherMissions* (Reports)* (ExpectedHouseRules) *

ExpectedHouseRule -> StandardWayCompletion | NewWayNonFailure

Where () indicates optional and * indicates potential several statements.

The implementation for the grammar can be found in Figure 1.a., for instance the requirement of specifying who is giving the command and what the target audience is implemented in the first two fields on the picture on the left. The ExpectedHouseRule portion of the grammar is implemented by how incoming commands are seen, at the bottom of the page, by specifying whether commands were followed in an expected way and whether they were successful or not (three examples are given, in the focused picture on the right of Figure 1.a).

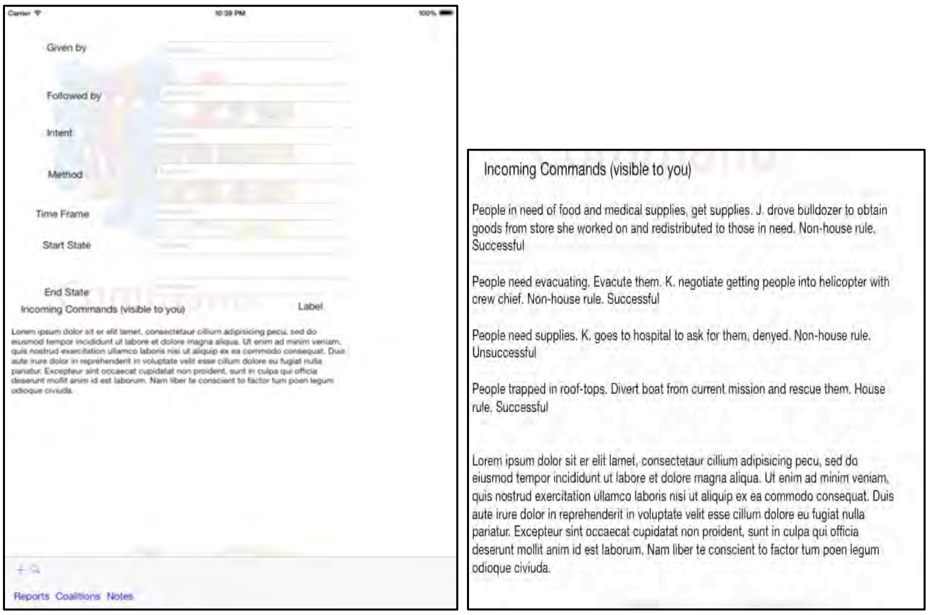

Figure 1.a. Implementation of command segment of grammar.

Figure 1.b. Implementation of report segment of grammar.

The purpose of having a formal grammar is to provide a way to create algorithms in a language that could be used by machine, hence our choice in using a regular grammar (we are not providing the actual machine implementations, but appreciate the importance to those who work in this area, so we have chosen to make such considerations at a fundamental level of our work). It is unreasonable to expect that one would be able to directly program a new language, and the closest one can expect in such a project is an implementation in the way we have.

Case Studies

The case studies and their analysis can be found in (Calderon et al.) we will now summarize the main findings, for more detail we refer the reader to the previous literature. With regards to command and reporting the main aspects we have analysed leading to success or failure of missions are:

- Human bias in following commands.
- Flexibility and rigidity of commands
- A (lack of) understanding of the interplay between: different commands, different elements of different commands.
- A temporal classification of command, communication structures and sensemaking.
- A structure of intent.
- A (lack of) understanding of organizational doctrine, house rules (which we define as expected ways of achieving certain goals, carrying out certain instructions) and organizational and individual culture.

We must remark that the case studies from real emergencies we have analysed did not have A.S. (autonomous systems, can be physical or non-physical) encompassed in them, and so we have made a prediction as to where A.S. would have been beneficial. Aside from obvious physical points in which they can assist humans, we are interested in how they can aid in the collective decision-making process which impacts individuals affected by crisis. Our analysis of usage of intelligent systems in emergency management is thus conducted from a person's perspective. This formed the academic basis for IntCris, Table 1 gives a summary exemplifying some features that were implemented as a result of academic studies; more details of implementation are given in the next section. At this point is worth noting that the implementation of our prototype is not solely based on case studies, seeing as this can often be thought of as "one-off" events, rather it is inspired by them. The prototype is hence best thought as being motivated by case studies together with extensive literature on considerations for failures during disaster. For example Turoff (2008) notes the problems during the aftermath of Hurricane Katrina which arose from "lack of coordination, cooperation and collaboration throughout areas of planning, mitigation, response and even consistency of recovery"; the study of coordination and collaboration of efforts is something IntCris is intended to facilitate. Other important literature that has inspired the creation of IntCris includes (Carver and Turoff ,2007; Gomez and Turoff 2007; Palen et al, 2007; White et al; 2008).

Personal	Case studies, literature.
Reporting	Case studies, military literature inspired the grammar, which was re-iterated post pilot study.
Command	Case studies and military literature inspired the grammar, which was re-iterated post pilot study.
Coalition	Case studies and documented reports of ad-hoc and official coalitions forming during post-disaster relief
Decision - making: chat	Deliberation to facilitate decision making is inspired by literature and case studies observed in social media websites during Hurricane Sandy
Decision –making: filtering	Case studies and conversations observed in social media websites lead us to deem necessary to implement such a feature

Table 1. Examples of aspects implemented and what constitutes the basis for the implementation.

DESCRIPTION OF PROTOTYPE

We have essentially created a collaboration software, helping collectives "help themselves" by facilitating information filtering into what is relevant from each user's perspective. This is done both at the user level, limiting how certain information is input (for example under the category "commands") and at the system itself, allowing users to input information a little more freely in some cases (for example, if chosen to input under the category of "personal") and then generating the filtering through the system. There are three main areas (report, command and notes) in which detailed information can be input, and in addition users can update the system as to where they see a shelter and other relevant information such as where nearest MREs (ready meals) distribution points are.

We will now describe the main features of the system, as well as give an overview of how information is categorized. The main features can be found in Table 2. Incorporating autonomous systems is a big portion of the novelty of the system and because it is hard sometimes to keep track of which features they are allowed to manipulate, these are explicitly stated in that table. A summary is that humans are the final decision-makers; autonomous systems are incorporated in a way that will ease the cognitive load on their human counterparts.

Coordination	This was designed to facilitate coordination between all stakeholders (humans, autonomous, agencies themselves, collectives, meta-collectives).
Learning	This is an overall system feature, an intentionally emergent property.
Information Gathering	Both humans and autonomous systems are able to facilitate this by providing information in any of the categories; personal, command and report.
Coalitions	Human and autonomous agents can input information. This is in case agents participating in particular coalitions wish to launch programs that will automatically update its members and which coalitions agencies belong to.
Sense-making	Left to human agents only. The current version has no means for an autonomous system to interact with this portion of the software, this is because it was intentionally designed for humans, but we might re-iterate future versions so that autonomous agents could make requests and send their replies between them or to humans.

Table 2. Main features and intended users (human or autonomous agent)

Coordination

During Hurricane Katrina we observed a failure to coordinate different missions within the same and across different organizations and hence we added single mission and multi-mission views, so the user can see details of a single mission as well as how it coordinates with other missions (official and unofficial). In an attempt to help users get a clear view of how everything is linked we have implemented the following:

• From a "single" command (or report) view, it is possible to view how that particular command (or report) links to other commands and reports within the same mission and across different missions.

• From the tree of commands (reports) within the same mission and across different missions, it is possible to select a single command tree and view that (in the sense-making portion of the software).

Learning

The chosen approach to dealing with unexpected situations means that the system's protocols (can be informally thought of as the collection of rules and known ways to achieve goals) has to learn new behaviour, as specified in the command and reporting grammar. In IntCris, it is possible to view which commands were successfully completed "as expected" and which ones generated new behaviour. This can be found in the grammar segments and implementation (Figure 1). This is based on many examples of agile behaviour observed during Hurricane Katrina, as well as a ripple effect of some new behaviour being transferred across different situations.

New behaviour is also learnt from information sharing, through the reporting mechanism. Another way to share information is through social media and also Personal Notes can be transformed into reports and shared with other users via that.

IntCris is is a constantly learning system, users are constantly inputting data which is being filtered into knowledge and information; then the system and its users are constantly learning and feeding that knowledge back in.

Information

To gather information, other than incoming commands, reports and social media feeds, it is also possible to search for locations of shelters, MREs distribution centers and first aid (and request other categories and then populate them) if/when shared by the organizations involved and those affected or able to see these. The idea of allowing anyone to input shelters, MREs and first aid locations is to allow the system to be self-filtering (similar to Wikipedia), so people will click a “quick add” or “quick remove” button when they are walking past a location and notice, for instance, a new shelter or that one is no longer available.

Another way to collect information is by participating in a live chat with users currently logged onto the application. The dispersion of information is done similarly. Information for our purposes has three very broad categories: personal, command and reporting, which we will now describe.

Personal notes:

These are notes individuals make for themselves with the option to share them via social media or reporting. Sharing them via a report will cause the individual to filter out some of his/her data so that it fits in with the reporting grammar implemented. Another way a user can share a note is simply by making it publicly available to all users (public button). The initial page to add a note is shown in Figure 2.

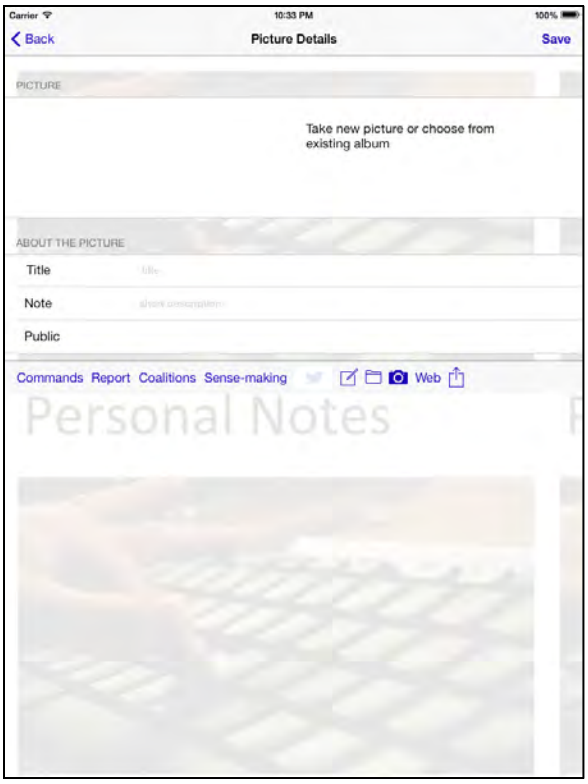

Figure 2. Personal Notes

Command and reporting

The implementation has already been described, but we have not yet related it to A.S. We have not dealt with how autonomous systems interpret command and reports, we are mainly interested in communications to facilitate human decision-making and thus our system considers incoming commands and reports from A.S.; we are not concerned with the engineering aspects of autonomous systems. Our task here is to consider what technology is available with regards to this type of intelligence and provide mechanisms for ease of communication (to humans).

Coalitions

There are numerous examples of official and unofficial coalitions formed during disaster relief, established prior to and ad-hoc during disasters. For example during Katrina a group of friends formed informal understandings with the police and the National Guard who passed them ready meals to distribute as well as information of survivors wishing to evacuate (Rodríguez et al, 2006). Another example is given by Humanity Road (Starbird and Palen, 2013). It thus seemed prudent to add to IntCris a coalition database, updated by its users (memebers of organizations, individuals from the public, etc.), for instance figure 3 shows a user being notified that a coalition has been found.

Moreover, organizations involved typically do not work together under "normal" circumstances; they might have engaged in training or even in coalitions during previous disaster management but they might have gone for long periods of none or little communication before being suddenly required to collaborate. This problem is too complex to be solved completely, there are many factors such as difference in culture and doctrine of organizations and agents involved so we acknowledge that we cannot make much progress in this are and instead just make coalitions transparency so that they are incorporated in with all the information provided by and to users.

Figure 4. Notification of match to official coalition

Sense-making

To make sense of all the information gathered, users could participate live chat, filter information by mission or filter information by locational relevance. The purpose of the live chat is to facilitate in the deliberation process (explained below).

Deliberation with other users

We currently have enabled live chat from points in the application where users are likely to make a decision (when receiving a report, when transforming personal notes into public information and when receiving a command) as well as from the designated decision-making portion of the application. A deliberation tool must in some way decrease the quantity of raw data helping its transformation into information or knowledge. Loosely speaking, this is typically done by analysis of data prior or post user input; doing it before user input requires greater human effort and doing it post user input could cause loss of potentially significant data. To get a "best of both worlds" scenario we have made a conscientous choice of having both in IntCris; where explicit deliberation is achieved, the input is completely unfiltered and left to users to decide how to chat to each other; other areas force users to categorize information prior to sharing it with other users (such as the reporting mechanisms).

Users can post structured information (report, command) or unstructured short "burst" of information through the chat functionality, or by sharing a personal note. This serves the purpose, as explained in the introduction of facilitating filtering of data into information without much cost to human cognitive effort and to loss of data. The rationale is that when users are able to categorize the data they wish to make public (or to selected members) they will make use of the report and command or personal spaces in the system, thereby pre-filtering the data to those receiving it; and when those posting data cannot do so either because they do not know how to or because of time constraints, they will make use of the chat functionality or simply post a personal note into public space, both are slightly filtered as the users are constrained by the user interface in the case of personal notes and by character limitations in the case of the chat. User interface constraints are something which cannot be avoided as presenting the input of information in a certain way will always cause users to alter the information, but that is something we will analyse in greater detail in future versions. The constraint of character limit seemed necessary; as we are trying to some extend to mimic the phenomenon observed by the heavy usage of microblogging during disaster, for that exact reason.

Filtering

Another way in which users can make sense of all the data available to them in time of crisis is by the explicit filtering functionality present in IntCris. We have currently enabled filtering of information by which locational relevance and by mission. We appreciate this is a very early starting point to explicit filtering, and so we have added a "request for new category" button so that when field-testing the applications, users can tell us as they need new categories what these are.

Filtering by location is done quite simplistically by determining the users present location and establishing what the nearest point of interests are; and to filter by mission the user must choose what mission he/she wishes to analyse in greater detail. By mission we mean broad categories such as rescuing within a particular location.

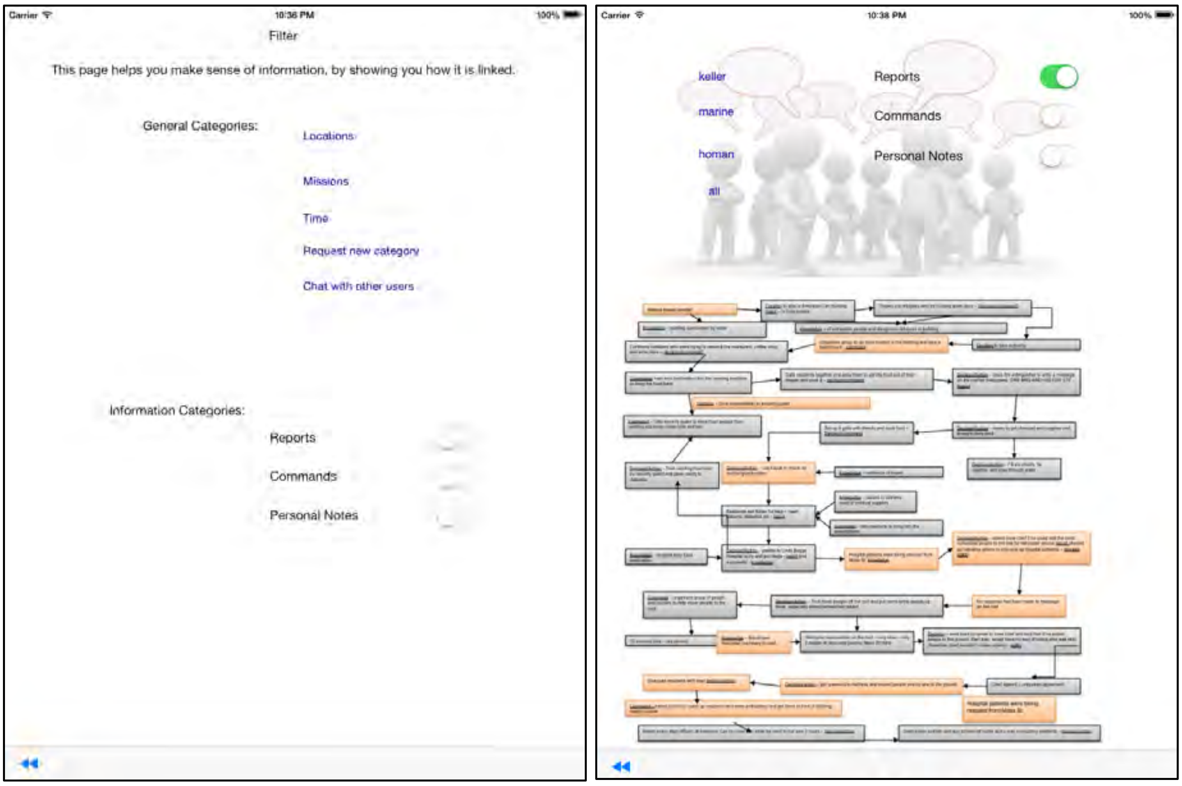

Figure 3. Initial sense-making page (left) and filtering a particular mission by reports (right)

Target Audience

IntCris is intended to serve official and non-official agents and coalitions, i.e. emergency responders as well as civilians on the ground (or remotely). We envision that future versions of this software will be developed for a more specific usage, for example paramedic groups.

CONCLUSION AND FUTURE WORK

Technology, social media and crowdsourcing are increasingly prevalent in emergencies and large-scale disasters. IntCris capitalises on these areas and extends current technologies through incorporation of the interactions between humans and autonomous agents. There is an increasing usage of technology during disasters and this app fits with current trend. It is the first of its kind to combine divulgence and gathering of information with coalitions and personal use, as well as diving information into self, command and reporting whilst consideration mission undertaken by humans as well as UAVs.

We have completed the first step in our research to understand how to create new technology that aids agile behaviour during a crisis. We studied real life interaction and communications as well as analysed social media communications in order to create a prototype. The next step will be to observe IntCris being used in simulations and "in the field" to understand what additional features must be implemented. Even before conducting such studies, we can make some additional hypotheses. For example, the IntCris will be able to harvest information from participating agencies (once they add themselves and allow for information to be harvested via their Twitter or other social media account); information such as ready meals and shelters is crucial for those affected (Figure 4 provides a proof of concept – the application detects user Location and mimics adding information of nearby shelters). This is currently all done by relying on users explicitly adding shelters, etc. we wish to alter this so the database is in addition automatically synced to named organizations wishing to participate.

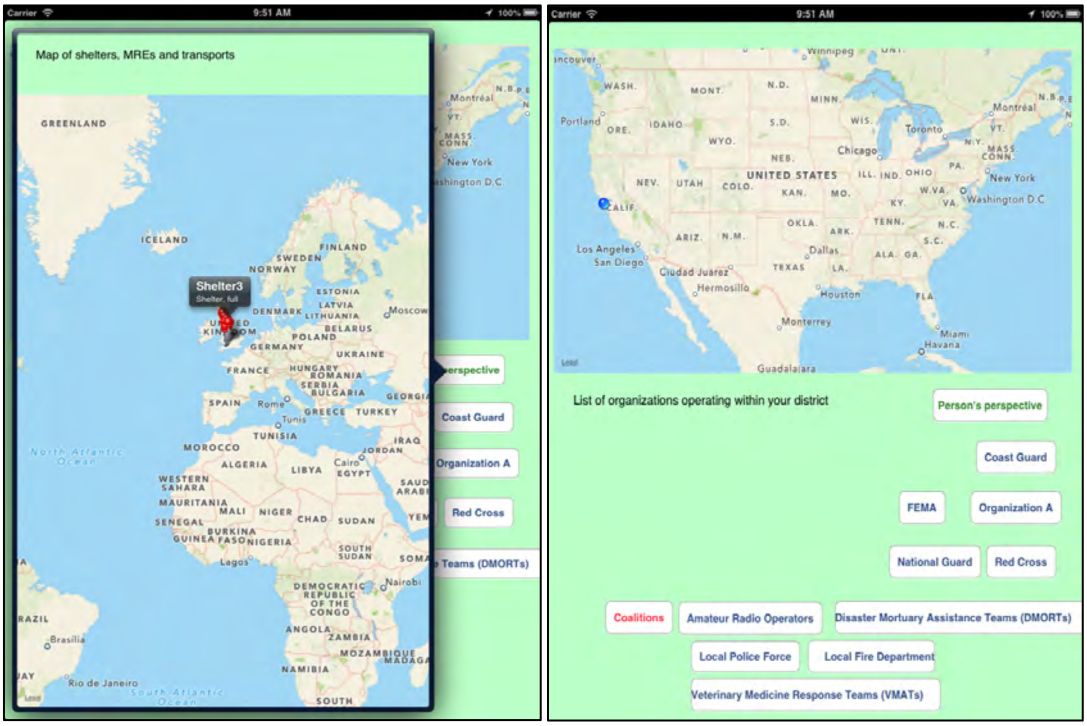

Figure 4. Immediate Information to victims (left), pop up from initial page (right) – proof of concept. The organizations listed are some of those involved in Hurricane Katrina and are for demonstrative purposes only.

We have recently conducted a pilot study to understand how reports, commands are followed and given by humans, through the prototype, we will then move on to estimating whether our incorporation of autonomous systems in IntCris is best-fitting and how it could be improved. Hence, we will conduct studies into impact of incorporating A.S. into system with regards to the features described. Calderon, A., Hinds, J., & Johnson, P. (2013). Leading cats: how to effectively command collectives. In
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