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Information System Supporting the Management of a Flooding Crisis in the City of Prague

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Abstract – **In this paper we present an information system improving situational awareness, communication and management during a flooding crisis. The system is based on the agent framework (JADE) and a blackboard like functionality, which enables rescue workers and services to improve communication, increase context awareness and activate rescue services. Observers in the crisis field, modelled as an agent, report about their observations using an icon-based crisis App on a smartphone. A prototype has been implemented and tested in field experiments.**

Keywords – **flooding crisis; crisis App; agent framework; decision support system; field experiments.**

I. INTRODUCTION

The city of Prague is situated along the borders of the river Vltava. This river is a typical rain river. In case of heavy rainfall in the Black Forest, close to the source of the river, the water level in the Vltava can rise up to 7 meters and threaten the old city of Prague. In the past, many actions have been taken to slope down the raise of the water. A cascade system of seven sequentially dams and corresponding front lakes has been built and can be used to buffer the raising water by opening and closing the doors in the dams in time. When the water level reaches at a certain height, then, dams in tributaries can be closed and dikes along the river can be breached to allocate water to selected areas.

In the event of flooding, the lower parts of the city will be firstly inundated and a set of responses have to be made in time. Citizens from this area have to be evacuated in time. Further, water and electricity supply also needs to be cut off in time. Meanwhile, metal barriers and dikes of sandbags should be built and dams have to be regulated to delay the raise of the water. The water level of the river is the crucial parameter for these necessary actions to be taken appropriately. Therefore, on different locations sensors are installed to measure the raise of the water and statistical models have been developed to predict the raise of the water the coming days.

In this paper, we research the role of human observers in crisis situations. The goal is to increase context awareness and communication between citizens of the city of Prague in case of a flooding disaster. A dedicated app, Crisis App, has been developed for smart phones enabling human observers to report their observations to the central crisis room. To support people that come from different background, the app provides icons to enable the user constructing messages for reporting situations. The collected messages will be used by the authorities in the crisis center for further decision making.

The idea to use an agent based system for communication between first responders in the field and crisis center has been applied in some crisis events and training sessions of first responders. The problem is that first responders prefer communication via mobile phones. But in case of big events this is no longer an option. The bottle neck is the automated processing of incoming messages. In this paper we present a special app using nonverbal communication based on icons. The use of icons enables automated processing of incoming messages. A running prototype has been developed and tested in several experiments presented in the paper.

We used a special Massive Open Online Course (MOOC) for the evaluation of the system because real life exercises with a real life flooding disaster are difficult to realize. For that reason, a MOOC has been developed with many exercises using simulations, movies and game technology. First responders as police officers, firefighters or medical assistants, execute the exercises in the MOOC and cooperate together in different roles and settings. On the other hand, we also employ the MOOC to increase the awareness of flooding disasters. Students from the Czech Technical University in Prague are stimulated to follow the distant learning course. Most of the exercises are group exercises and students are able to play different roles as first responder. At this moment the MOOC on the flooding of Prague is a free elective course and not a compulsory course. To increase the interest and participation of students, the MOOC material is also used in regular courses and training sessions of first responders.

The outline of the paper is as follows. Section II presents related work. In Section III and IV, respectively, we describe the system and its architecture. Further, we discuss the (field-) experiments in Section V. Finally, we conclude how far the research goals are realized in Section VI.

II. RELATED WORK

Disasters can happen anywhere, anytime. Rodriguez et al. [1] collected papers about possible disasters in the world, its historic development, its impact and prevention measures. This handbook describes disasters and lessons learned from disasters. There is a focus on social aspects, mitigation, communication and how to return to the stable situation. In the research section there is a focus on methodological aspects, management and the role of mass media during disasters. For more details, the cases that occurred in Europe were collected in Begum et al. [2].

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The flooding in 2002 in Austria, Czech Republic and Germany was one of the most devastating disasters in history [3]. In the paper there is a special chapter on the flooding of the city of Prague. It started with the inundation of the lower parts of the city along the river and the islands in the river. The water level raises more than 9 meter and just in time before the old historic city was flooded the raising of the water in the river stops.

Most of the metro tunnels were filled with water. It proves that under the city, there were many caves gradually filled with water. There was enormous damage to the electricity and communication system, water supply, sewers. One of the lessons learned after the flooding disaster was that the bedding of river should be broaden, water from confluent streams should be regulated and dams with artificial lakes in front of it should reduce the raising of the water. There was a special focus on the failing communication system. This paper is focused on a solution for on the failing communication and observation system to improve the crisis management of the city council.

In the Netherlands an Institute was founded for crisis management. For many years the country suffers from flooding from the sea, deltas and rivers. A society for people working in the field of Information Systems for Crisis Response and Management (ISCRAM) has been established [4]. ISCRAM organized yearly conferences since 2004. The ISCRAM Association's primary mission is to foster a community dedicated to promoting research and development, exchange of knowledge and deployment of information systems for crisis management, including the social, technical and practical aspects of all information and communication systems used or to be used in all phases of management of emergencies, disasters and crises.

Holtz et al. [5] had analyzed the causes and resulting damages of flooding disasters and concluded that there would need for in-time information system to inform citizens about the flood development as well as a better coordination of resources and actions at the onset of a flooding. Hence, Information Communication Technology (ICT) would be potential in crisis situations. The role of ICT during a flooding crisis is the focus of this paper. Therefore, a decision support system to support people in critical situations and during evacuation was developed.

Another prototype to support crisis management was developed by Ianella et al. [6]. It was based on a review of the information structures and requirements for crisis centers. In fact the paper provides a design for a crisis information system. The system focused on incident notification and resources messaging.

Further, research on the use of Geographic Information System to support decision makers was investigated by Sklnář et al, [7]. It utilized mathematical models to predict water levels, water depth and velocity. Similar models were used to simulate the flooding of the river Vltava in Prague.

On the other hand, Palmer et al. [8] explores the use of smartphones for collaboration and data collection during disaster events. They developed a framework to build apps on Android, which allows the user to create, share, and distribute data independently, avoiding issues of connectivity to centralized resources. Our crisis App discussed in the paper is quite similar.

Smartphones can support people during mitigation as an effort to reduce loss of life and property by lessening the impact of disasters. Rothkrantz [9] introduced a communication network for crisis situations based on smartphones. Users in the field can communicate using a dedicated icon-based language, to report about their position and context situation and to receive information how to reach safe areas. Messages are ordered by the intensity of the emotional content. The users can be tracked by their GPS position and this information is used as input of a special dynamic routing algorithm based on ideas from Artificial Life, called Ant Based Control.

Community collaboration through crowdsourcing and journalism activities brings the use of Internet and mobile phones together to communicate disasters via popular media [10]. During the Hurricane Katrina 2005 [13], people used social network, Wikipedia, blogs, photo and video sharing, and websites to report the situations, harvest information, offer shelter, jobs, and emotional support. Mobile messaging have been used extensively during the China SARS epidemic in 2003 to inform others about the physical locations of apparent SARS victims [12] and after the underground bombings in London, UK, to report structural damages in underground surroundings [13].

For designing such a successful emergence response information system, Turroff et al. [14] defined four general principles, namely: (1) Prevent information overload (show relevant information only); (2) Improve situational awareness (provide and review up-to-date information and context); (3) Support configuration (adaptable priorities and filtering); and (4) Support role and task transfer (monitor and manage tasks and availability of personnel). Further, they described 12 fundamental roles supported by an emergency management system, such as: (1) Request resources (people and equipment); (2) Allocate, delay or deny resources; (3) Report and update situation; (4) Analyze situation; (5) Edit, organize, and summarize information; (6) Maintain resources (logistics); (7) Acquire more or new resources; (8) Oversight review, consult, advise; (9) Alert all with a need to know; (10) Assign roles and responsibilities when needed; (11) Coordinate among different resource areas; and (12) Priority and strategy setting (e.g., command and control). We recognized these roles and implemented. In our system, the role 1 will be performed by sensors and human observers reporting about their observations. The role 3, 4 and 5 will be performed in the central crisis center; whereas role 9 will be performed by our crisis alerts. The ideas of Turoff et al were presented and discussed on the ISCRAM conferences organized by the DECIS lab [4].

Nevertheless, disaster preparedness is a key to lessen the impact the impact of disasters on vulnerable populations and to be ready for an organization and government of an influx of activities. For this, Raikes et al. [15] reviewed papers related to pre-disaster planning and preparedness for floods and droughts. They assessed the governance and management of pre-disaster planning and found knowledge gaps between different stakeholders in the crisis management that could hinder decision making process and waste of resources, time and effort.

Rothkrantz and Fitrianie [16] address the issue by developing a MOOC based on the case of flooding disaster in Prague. The goal is to increase awareness of citizens in

Prague on the disaster. It provides a training tool for first responders to train crisis activities in a virtual world and includes management games enabling students to play different roles in the management team.

III. Overview of The System and Its Tools

We developed a distributed system in which people in the disaster area are able to report about crisis events and can lead themselves to safe areas while at the same time serving as field sensors that share information about the disaster areas. In the next section, we will give an overview about the system. Further, we will describe the tools used in the system, such as the Crisis App, the blackboard of the data sharing and distribution, and the Java Agent Development framework, the (JADE)-based multi agent system for processing the incoming messages.

A. Overview

As a scenario, we may assume that during a disaster event, first responders and civilians are distributed all over the disaster area, i.e. along the Vltava river. From their position, they could observe situations in their surroundings, such as raising water, people and animals in need, and so on. They can send text messages to report this to the crisis center. The challenge is to classify and interpret these messages automatically. Moreover, there are living many foreign people in the city of Prague, who do not master the Czech language. Pictures can also depict the events. However, an automated processing of pictures is even more complicated because of their ambiguous semantic interpretation.

A dedicated App has been developed for smart phones enabling human observers to report their observations to the central crisis room. To address the language issue, a predefined set of icons has been designed displaying critical flooding situations. Observations about crisis events and incidents, remote in place and time, will be fused and further processed in the central crisis room. Decisions from the crisis team on next steps are based on a decision support system. The city of Prague has a crisis plan for flooding disasters used by human decision makers during training in the past. The rules, plans and scenarios from the crisis plan have been implemented in the decision support system.

We model every involved citizen and device as an agent. An agent is defined as an autonomous system able to observe its environment, reason about that information and take some actions. All agents cooperate together using an agent framework, JADE. The agents place all the observed information on a blackboard like system. The blackboard is connected to a knowledge database composed of the crisis plan of the city. The crisis plan is converted to a rule-based system. Dedicated agents are defined and work together. Other agents will trigger knowledge rules or procedures in the knowledge base. How the agents process the incoming messages will be discussed in Section IV.

The system has been implemented to a running prototype. At regular times first responders have an exercise where a flooding disaster is simulated in a real-life environment. Some flooding events are simulated such as victims, evacuees, breaching dikes, raising barriers and field hospitals. All the communication is realized by users, using their smart phones, modelled as an agent, in a Multiple Agent Network (MAS).

B. Crisis App

Fig. 1 shows the interface of the developed Crisis App. We developed the app based on the analysis of logging of mobile messages during several flooding simulations [4], which reveals the following categories:

1. SOS-alerts calling for medical assistance or emergency rescue, such as assistance for people with medical problems (e.g. hart problems), drowning persons, and injured or wounded persons.
2. Message-alerts calling for assistance. Such messages were sent during sudden evacuation, for example in the case of missing people, getting lost or needing assistance from boats.
3. Observation alerts reporting situations in the field, such as the height of the water river, problems with dikes, blocked roads, inundated bridges, and so on.
4. Routing to save areas informing location and how to reach them.

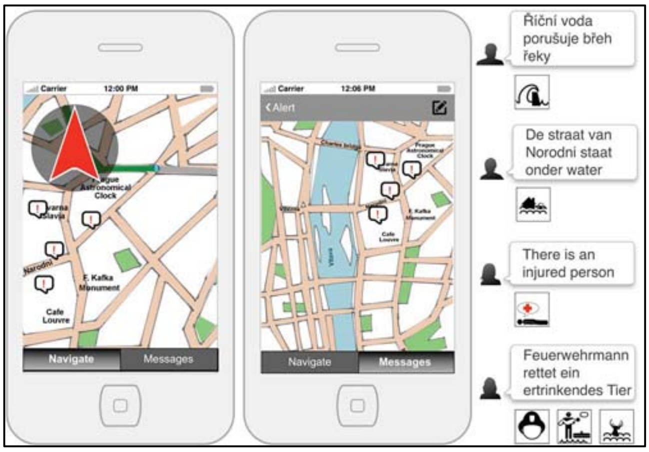

Fig. 1. Interface of the crisis App with Examples of Icon-Based Messages

Using the toolbar at the bottom, the user can choose *Navigate* and *Messages* options. On the Navigate interface, an arrow is used to point to the closest safe area; whereas on the Messages interface, the users can report their observations and read reports from other people in the area.

Fig. 2 shows examples of icons, provided by the app. Each icon has only one specific meaning. A message can be constructed using a single icon or a string of icons. A time stamp and GPS coordinate will be attached to every message. At the crisis center predefined verbal labels are attached to the messages. Sometimes the semantic interpretation of a message is ambiguous, even in the case of multiple observations of the same event. An example is a drowning person, floating along the water. The location is changing corresponding with the displacement of the drowning person.

The current version of the Crisis App is developed based on the world model related to a flooding crisis around the Vltava river at Prague. Therefore, the set of icons are provided and limited to this context in focus. The users can only use these icons to construct messages on their smartphones. They are selected based on an analysis of mobile alerts during a training session around flooding and a report of the flooding crisis in Prague [3, 7]. Hence, the number of possible messages created is also limited. On one hand, the users can only create messages on a limited kind of events. On the other hand, we can reduce the ambiguity of the interpretation of the message.

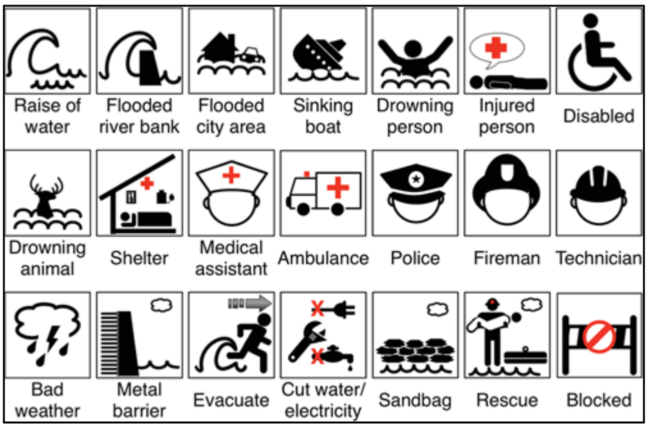

Fig. 2. Examples of icons in the crisis App

C. Blackboard

The concept of blackboard system is well known in the area of artificial intelligence and used already in the 80's. Fig. 3 shows the architecture of our blackboard system. The blackboard system runs on the server of the system. All incoming messages are placed on the blackboard system. They are ordered in a matrix structure. The GPS-coordinates is placed along the x, y axis and time along the z-axis. Besides observation reports from people in the disaster area and operators in the crisis center (i.e. shared control rooms), data can also come from sensor measurements, e.g. the river water level sensor.

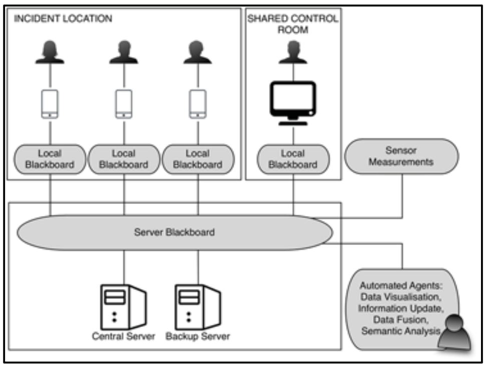

Fig. 3. Architecture of a Blackboard system

The incoming messages can be redundant and ambiguous. Observers can even report a misinterpretation of occurring events. Therefore, four types of dedicated agents are designed to process the incoming data: (1) visualization agents; (2) fusing agents; (3) updating agents; and (4) semantic analysis agents. *Visualization agents* are responsible on displaying the incoming messages on a digital map of the crisis area. *Updating agents* update data on the blackboard and refresh the information displayed on the map at regular times. The updating time depends of the context. In case of upcoming/ongoing crisis many messages can be expected. To prevent concatenation, the map has to be refreshed regularly. Deleted messages are saved in a historic file and can be reproduced again if necessary. *Fusing agents* fuse messages that report about the same event and come from the same time window and area. The time stamps and GPS location of the message allow the agent to group the incoming messages. *Semantic Analysis agents* interpret the incoming icon-based messages and attach a verbal label. Observers may report about similar events using different icons. Therefore, these agents work together with fusing agents to analyze the similarity of the messages.

D. JADE

Communication and data processing is realized by agents as independent and autonomous software modules. The agents are able to cooperate or compete together. These agents run on a platform provided by JADE. The Java Agent Development framework (JADE) is a software framework implemented in the Java language. This framework enables the implementation of multi-agent systems (MAS) according to the Foundation for Intelligent Physical Agent (FIPA) specifications. The Mobile devices, running the crisis app, are connected and sharing data between them.

In our case, the agent platform has been implemented on a central server. An agent platform is distributed across different computers. Therefore, it is possible to extend the current system and creating other types of agents. Replication of the system across several nodes can provide a backup in case of a system crash.

Messages exchanged by JADE agents are formatted according to the agent communication language (ACL) defined by the FIPA international standard for agent interoperability. This format comprises a number of fields such as the message sender, its receivers, its performative and the message content.

IV. Architecture and Implementation

Fig. 4 displays the global architecture of the Crisis Alert System (CAS). A prototype of CAS has been developed [18]. The server and the multiple client agents run on the JADE framework and form a blackboard like system. The central component in the architecture of the crisis management system is played by the blackboard system. Its infrastructure runs multiple subsystems, such as task overview, organization overview, a geographic information system, a communication part and a general incident information part.

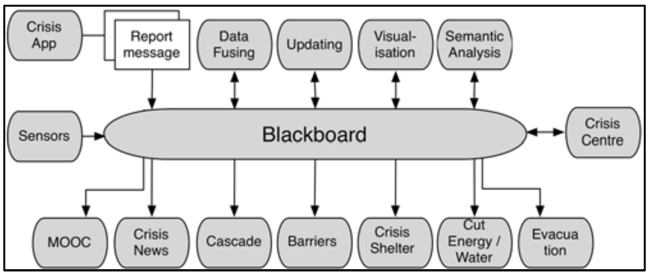

Fig. 4. Architecture of the Crisis Alert System

The input to the system is composed of information of human observers via the Crisis App on their smartphone (Fig. 4). Another input is from smart sensors that are distributed over the whole crisis area for measuring the height of the water in the river and upcoming water after a dike breach, or other prediction systems.

The information on the blackboard is processed by different agents and will activate different actions, initiated by rules in a knowledge base. Two clusters of activators triggering actions are: (1) regular crisis incidents and (2) planned incidents. *Regular Crisis Incidents* occur when there are calls from people who ask for assistance in the case of medical problems and other related calls, such as for the assistance of elderly, disabled people during an evacuation, people isolated by surrounding water, people who need help to reach safe areas and so on. These calls are not planned calls and trigger a procedure of actions. On the other hand, *Planned Incidents* triggers planned actions in the crisis plan. They are executed when the river water has reached to a specific level of height. These necessary actions, such as updating the MOOC, daily news on the Crisis App, regulate the dams in the cascade, building barriers, preparing and informing about the crisis shelter, cutting energy and water supply, and evacuation order, will be discussed in more detailed in Section V.

The functionality of the client and server part is provided by agents, namely a client agent and a server agent. These agents run on a JADE container that has to be activated first. When the server is started, it runs `Main.java`. After the user has successfully signed in, the main class calls `MainApp.java`. Here the JADE runtime is initialized and the `ServerAgent` is created. This agent is responsible for registering new client agents and sending them up-to-date incident data, e.g. informing the current situation to users via Crisis App whenever they login to the app. Another task for the agent is to store incident messages, and retrieve and forward new up-to-date interpreted data to all registered clients. Although creating a new incident is initiated at the client side, the server is responsible for creating the actual incident object and creating a new unique incident ID.

To perform its duty, the server agent keeps track three information (Fig. 5): (1) all agents that are identified in JADE; (2) the incidents that occur in the real world; and (3) the related emergency services. The agents' activities are monitored using a dedicated class, so-called `AID`. Whereas, the list of available emergency services is stored in the class `Professional`.

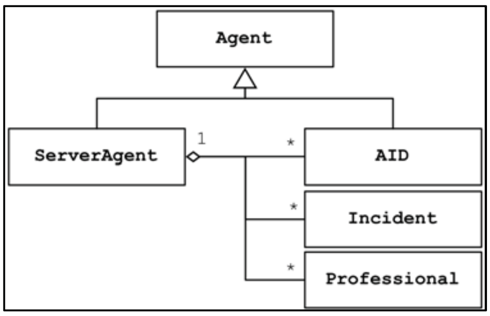

Fig. 5. The `ServerAgent` Class Diagram

All agents in CAS respond to messages received from other agents and send messages themselves. The client agent registers with the server, receives the latest incident data and displays the information on the user interface. Just as the server agent, the client agent keeps track of different information, such as: (1) all agent that are identified in JADE; (2) all incidents that are updated by and received from the server agent; (3) the emergency services that are selected by the server agent; and (4) all events that occur on the user interface. In particular, the user interface is initiated in a class called `SelectIncidentFrame`, which is an extension of the Java `Frame` class. The diagram class of the `ClientAgent` is shown in Fig. 6.

The CAS agents respond to messages received from other agents and send messages among themselves. JADE agents communicate using ACL-based messages. The receiving agent has to check what kind of message is received and respond accordingly.

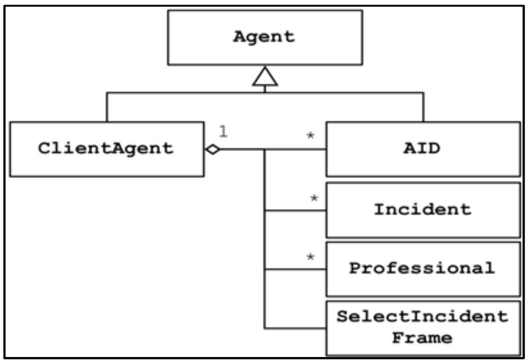

FIG. 6. THE `ClientAgent` CLASS DIAGRAM

Although an ACL message has fields such as receiver, performative and content, there is no general field for a subject or message type. JADE does, however, support topic-based messaging. Topics can be seen as a sort of channels with a certain subject. Agents can publish messages to a channel and subscribe to a channel to receive all messages published to it.

IV. CRISIS ACTIONS

Observation reports via the crisis App and sensor measurements, activate rules in the knowledge center. These rules trigger actions and procedures. At this moment, only suggestions will be made by the system. As a decision support system, the system alerts and supports the crisis center. The execution should be verified and permitted by the crisis center. One of the messages to citizens is Crisis News communicated via the Crisis App. These news alerts alerting also people in the crisis management team.

As stated before, the crucial parameter is the height of the water level in the Vltava river. Via simulation models the impact of the flooding at different levels of the water is computed. The surrounding of the river is composed of peaks and valleys. Using finite element models, the effect of the instreaming water after a breach of a dike is computed. To be expected, the simulation will first depict the flooding in the lower parts of the city. Then, when the height of the water moves to the next level, the higher parts of the city will also be flooded. If the water level passed a specific threshold, additional rules will be activated. In this section, eight crisis actions (Fig. 4) will be discussed in details.

A. MOOC on Flooding in Prague

In the pre-crisis time, a lot of actions have to be executed. A problem with crisis in general and flooding disaster specifically is that citizens wait for actions until the very last moment. Just after a crisis citizens are more sensitive and take preparation for the next flooding. But when the time passed by, the sensitivity for flooding crisis is decreasing. Therefore, a dedicated MOOC using the case of the flooding disaster in Prague has been developed to increase the crisis awareness of citizens and to provide training facilities for first responders (Fig. 7).
In one of the assignments, students have to play different roles in the crisis team to get familiar with different aspects of events and actions during a flooding crisis.

Fig. 7. The view on the Charles bridge in Prague (the MOOC interface)

The problem with distant learning of voluntary courses is that it attracts a few students and the drop-out rate is very high. During the Corona crisis all universities were closed in Europa. Distant learning by video lectures, MOOCs and online assignments, was the only option. The interest in distant learning is increasing and attracts more students.

B. Crisis News on the Crisis App

Communication during a crisis is very important. Citizens are supposed to communicate via social media. Local TV and radio have a special channel with crisis news such as interviews and TV reports. Nevertheless, channels with visual information catch the most attention of the people. On the other hand, the current practice shows that the crisis team of the city only used their website to inform citizens about the current situation and ongoing and to be expected actions.

One of the actions is a daily publication of a crisis newspaper with additional breaking news issues. A prototype of such a digital newspaper has been developed with possible headings and text fragments. An important item is the weather forecast (Fig. 8). The current version uses a weather forecast system, Medard that was developed by the Academy of Sciences of the Czech Republic [19].

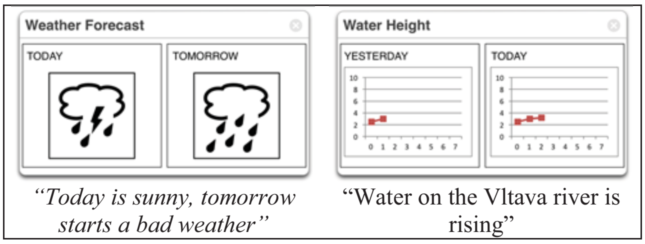

Fig. 8. Examples weather forecast in crisis News

C. Closing Dams in the Cascade Barrier

Along the Vltava river, the cascade of seven dams has been built (Fig. 9). The cascade was designed to delay the raising of the water and postpone and reduce flooding.

Fig. 9. Dams in the Cascade Barrier

In the case of upcoming flooding, the water in the lake will be filled with water and the doors in the barriers of all dams will be closed. If the level of the water passes a certain threshold, then the barrier will be opened again. The opening and closing of the barriers is managed by an automated system that uses information about the level of the water in the river and lakes.

D. Metal barriers and removable dams of sandbags

One of the earlier actions taken after the water is flooding the quays and dikes, is building metal barriers in prepared slots and dams of sandbags in the city of Prague. This will delay the raising of the water in parts of the river and waiting is no longer an option, because no one knows the seriousness of flooding in advance. Delaying the rise of the water can provide time, while we are dealing with other crisis measurements. In the city of Prague, some restaurants and hotels are built close to the river. Therefore, metal barriers can provide more time for evacuation of people and goods from these places. Unfortunately, in the case of a devastating flooding due to the threshold capacity of the water level is already passed, both barriers and dams would be also breached and flooded.

E. Cut off Water and Energy Supply

During a flood, a hazardous flow of electric current can occur from submerged or damaged electrical equipment and the associated risk of electrocution from water damaged appliances. Therefore, in the city of Prague, the current practice dictated that if the lower parts are already flooded and the higher part is in danger, the energy and water supply to houses will be cut off. This will force people to evacuate the house. However, at the same time, the doors to the underground metro will be closed. To avoid chaos, people have to be informed in advance. This because citizens often postpone their evacuation until the last moment. On the other hand, metro can facilitate evacuation of people from threaded areas.

In 2002 the metro was not closed in time by human failure and lack of maintenance. To avoid the same problem occurs, the developed system will alert the crisis center in time, and special around doors and tunnel tubes measure of the necessary action is executed.

The metro stations will be closed in conjunction with raising level of the water. The stations will be closed in sequential order.

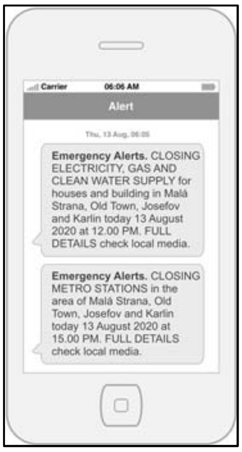

Fig. 10 Warning Sent to the Citizens via the Crisis App

Firstly, those in the lower parts will be closed, and then the stations in the higher parts will be next. The news will be published on the Crisis App (Fig. 10). Citizens get a warning that after closing the metro stations close to the river it is not possible to travel from new town to the old town. Also trams and busses are not allowed to cross the bridges. Closing metro stations will happen in parallel with evacuation. To evacuate, citizens have to use metro stations in the higher parts. A map of open and (to be) closed metros stations will be distributed via the crisis App.

F. Crisis Shelter

Just before the first living areas will be completely flooded, citizens have to be evacuated to safe areas. These safe areas are temporary and usually located on higher parts of the city, e.g. parks and squares. In the safe areas, tents and mobile houses are built to provide food and drink, shelter, electrical supply and medical help for the refugees. As soon as possible, evacuees in this shelter have to be routed to other safe places at remote places, e.g. to other families, friends or other public places.

G. Evacuation

Evacuation of people from a threaded area has been described in detail in the crisis plan and is implemented in the current alerting system. As mentioned previously, immediately after dikes are flooded, citizens from this area should be evacuated. People are alerted and routed by the Crisis App to the closest safe area. Police cars and firetrucks with speakers are crossing the streets to create the way to the safe area and controlling the process. Taxis and ambulances are used to evacuate sick and disabled people. A routing scheme and time schedule of the cars are distributed via the Crisis App.

V. Experiment

The Research Lab DECIS at Delft was founded by the Universities of Delft, Amsterdam, Thales and Institute of Applied Research TNO. One of the research focuses of DECIS was crisis management and there was a strong cooperation with the Dutch police, fire Brigade and Medical Support and other institutes of first responders. Most of the systems presented in this paper are developed by researchers of the DECIS lab. The DECIS lab as coordination center of Crisis in the Netherlands enables test facilities. At regular times DECIS organized with all cooperating partners, huge training exercises on themes such as flooding, nuclear disasters, fires and terroristic attacks. Over the years DECIS partners developed a specific model, based on cooperating agents using Cougar software. The authors of this paper participated in all exercises and had a leading role in the flooding experiment. Results are presented in the report Combined Systems [4]. The project's contributions include: (1) a new model for the development of crisis management support systems: the Combined Systems view (2) new technology in the form of intelligent building blocks and (3) a diverse and dedicated crisis management research community.

In the flooding experiment, simulating flooding of the big rivers in the Netherlands, the focus of the experiment was on communication. Usually first responders communicate by C2000, a special telephone network. By the rise of social media at those days, the focus of the project was on communication by mobile messages. Imran et al. researched Disaster-Related Messages in Social Media [11]. In the experiment we tested the approach of communication between rescue workers and the crisis center by mobile messages using our Crisis App.

In the flooding experiment, a virtual flooding was simulated. A flooding scenario was developed starting with raising of the water, breaching dikes, building barriers, evacuation, cutting the water and energy supply, and closing bridges, tunnels and metros. The scenario included a report about, rescue and evacuation of injured, sick and disabled people. First responders in the field got regularly an update about the situation from the crisis center. Especially the evacuation of farmers in the region with all their animals was complicated with a lot of logistics problems. Part of the farmers was not willing to move and quick actions of police were necessary. All events were reported by phone and mobile messages.

It proves that updates of mobile messages were delayed. Phone calls were a faster way of communication and allow clarification and specification during the calls. Mobile messages provide summary and a conclusion afterwards. During the evaluation of the disaster, all mobile messages were processed automatically and compared with the events from the crisis generator and telephone calls. A preliminary conclusion is summarized in the next table. More details can be found in the DECIS reports [4].

TABLE 1. RESULTS FIELD EXPERIMENTS

	Automated processing	User preference	Speed of comm	Number of messages
Telephone comm.	No	Yes	Fast	Average
Mobile Message comm	Yes	No	Slow	Huge

At regular time first responders of the city of Prague participate in training session, most of the time focused on flooding disasters. Real life training sessions on flooding disasters are difficult to organize. For that reason the special MOOC on the flooding of Prague has been used in training sessions. In the summer of 2018 and 2019 first responders and visiting students from the Czech Technical University in Prague participated in training sessions using the MOOC. Similar results have been described in [20]. Most of the visiting students don't master the Czech language. The nonverbal icons enable a specific language independent communication.

VI. CONCLUSION AND DISCUSSION

Since people in the disaster area, as a resource, has rarely received attention from disaster management researcher, many disaster response solutions usually focus on supporting emergency services. In this paper, supported by technological advances in smartphones with GPS and data connectivity, an information system has been developed and presented that enables people in the disaster area as a potentially vital information supplier. They can help to construct an emerging overview of the disaster without burdening the already overwhelmed emergency services. With better knowledge of the disaster situation, aid and rescue activities can be assisted more effectively. At the same time, as a decision support system, the developed system is able to reduce the overload of operators, failures, and waste of resources, time and effort. In the field experiments, the system has allowed people to collaborate and share information using prevalent mobile technology.

Future work yields on the exploration for methods and techniques for processing, interpreting, analyzing and clustering a huge number of incoming reports and make them meaningful for disaster managers that include dealing with filtering, selective perception, information overload, misinterpreted and biased information. Another important future work for this research might be the incorporation of credibility weighting to the information, so that the reliability of the data gathered can be ensured (e.g. a single report from a police officer versus hundreds reports from regular citizens).

REFERENCES

[1] H. Rodriguez, W. Donner, and J. Trainor (Eds), "Handbook of Disaster Research". Serries: Handbooks of Sociology and Sociology Research. Springer 2017.

[2] S. Begum, M.J.F. Stive, and J.W. Hall (Eds.), "Flood Risk Management in Europe", Innovation in Policy and Practice, Serries: Advances in Technological and Hazards Research. Springer 2007.

[3] Risk Management Solutions, Inc., "Central Europe Flooding, Event Report, August 2002", Event Report, 2003.

[4] Combined Systems, Report DECIS Lab, 2006.

[5] K. Holz, G. Hildebrandt, and L. Weber, "Concept for a Web-based Information System for Flood Management". Natural Hazards 38: 121-140, 2006.

[6] R. Iannella and K. Henricksen, "Managing Information in the Disaster Coordination Centre: Lessons and Opportunities", Proc of ISCRAM 2007.

[7] P. Sklenář, E. Zeman, J. Špatka, and Tachecí P, "Flood Modelling and the August 2002 Flood in the Czech Republic". In: Begum S., Stive M.J.F., Hall J.W. (eds) Flood Risk Management in Europe. Advances in Natural and Technological Hazards Research, vol 25. Springer 2007

[8] N. Palmer, R. Kemp, T. Kielman, and H. Bal, "RAVEN: Using Smartphones for Collaborative Disaster Data Collection". Proc. of ISCRAM 2012.

[9] L.J.M. Rothkrantz, "Mitigation using Emergent Technologies". In: Teodorescu HN., Kirschenbaum A., Cojocaru S., Bruderlein C. (eds) Improving Disaster Resilience and Mitigation - IT Means and Tools. NATO Science for Peace and Security Series C: Environmental Security, pp 203-223, Springer 2014.

[10] D. Gillmor, "We the Media: Grassroots Journalism by the People, for the People". O'Reilly Media, 2004.

[11] M. Imran, S. Elbassuoni, C. Castillo, F. Diaz, and P. Meier, "Extracting Information Nuggets from Disaster-Related Messages in Social Media", In Proc. of ISCRAM 2013.

[12] P. Law and Y. Peng, "Cellphone, Internet, and the SARS Epidemic". In Proc. of the Int. Workshop on Mobile Technologies and Health: Benefits and Risks, 7-8, 2004.

[13] L. Palen and S.B. Liu , "Citizen communications in crisis: anticipating a future of ICT-supported public participation". In Proc. of the CHI, 727-736, 2007.

[14] M. Turoff, M. Chumer, B. Van de Walle, and X. Yao, "The Design of a Dynamic Emergency Response Management Information System (DERMIS)", J. of Information Technology Theory and Application, 5(4):1-35, 2004.

[15] J. Raikes, T. Smith, C. Jacobson, and C. Baldwin, "Pre-Disaster Planning and Preparedness for Floods and Droughts: A systematic review". Int. J. of Disaster Risk Reduction, 38, 2019. DOI: 101207

[16] L.J.M. Rothkrantz and S. Fitrianie, "Public Awareness and Education for Flooding Disasters". In: K. Holla, J. Ristvej & M. Titko (eds.), Crisis Management - Theory and Practice, IntechOpen. DOI: 10.5772/intechopen.74534

[17] L.Rothkrantz. "Integration of MOOCs in regular courses". Proceedings of the 19th International Conference on Computer Systems and Technologies, 2018, pp 144-151.

[18] B.J.Vink. "Incident Management Information and Communication System (IMICS). Thesis TUDelft, 2009.

[19] E. Pelikan, "Forecasting of Processes in Complex Systems for Real-World Problems", Tutorial. Neural Network World 6(14): 567-589, 2014. DOI: 10.14311/NNW.2014.24.032

[20] L. Rothkrantz. "Affective didactic models in higher education". International Journal of Human Capital and Information Technology Professionals (IJHCITP), 8,4, 2017.