Exploring Cooperating Smart Spaces for Efficient Collaboration in Disaster Management

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ABSTRACT

This paper discusses the applicability of Cooperating Smart Spaces in the disaster management realm and their potential to increase the efficiency and effectiveness of rescue relief teams. The Cooperating Smart Space is a novel concept that combines and extends pervasive computing and social computing to support smart space management and community collaboration. Based on an analysis of current practice, we illustrate how the concept can be exploited in the assessment of a disaster scenario in order to improve information management, collaboration between expert teams and cooperation with online volunteers outside of the disaster zone. We present the results of an initial user evaluation by disaster management experts and conclude with important implications for the design of a Cooperating Smart Space platform.

Keywords

Pervasive computing, Social computing, CSCW, Crowd participation, Disaster Management.

INTRODUCTION

The paradigm of pervasive computing is that of environments where objects that are becoming increasingly intelligent and provide information and services to the user when and where needed. As of today, pervasive computing environments, also often called smart spaces, are mainly designed to address the needs of individual users. Although they support multi-user operations, they assume interactions primarily between users and the environment, not amongst users. This neglects an important part of human behaviour: socializing. At the same time, the recent development and popularity within social computing, i.e. digital systems that support online social interaction, has happened more or less in isolation from the developments in pervasive computing. We propose to integrate the two paradigms and introduce Cooperating Smart Spaces (CSS) that extend pervasive systems beyond the individual to dynamic communities of users. In order to evaluate the CSS concept and its proposed features, our work involves three different user communities: a student community, an enterprise community and a disaster management community. This paper discusses the latter case. Based on an analysis of current practice, we illustrate how the concept can be employed in the assessment of a natural disaster in order to improve information management, collaboration between expert teams and assistance from volunteers outside of the disaster areas. The paper addresses two questions: 1) How can we apply the CSS concept in specific situations involving disaster assessment experts? 2) How do disaster assessment experts perceive the proposed CSS features? We present an initial user evaluation and its results.

The concept of Cooperating Smart Space (CSS)

Extending the concept of smart space, CSSs include the basic capabilities of a smart space and thus support the seamless and unobtrusive interaction of the user with devices and services in his/her environment. A main goal in smart spaces is to let the users concentrate on their tasks rather than on the computing activities provided by the space to support their tasks. To achieve these goals, smart spaces are often designed to be context-aware, i.e. they can adapt to the user's needs and situations, and to be pro-active, i.e. they can manage decisions and behaviours on behalf of the user. Beyond the basic capabilities of smart spaces, we propose to add a social dimension to CSSs. Our focus is the management of communities of people who share common interests or goals, communication between community members and the sharing of devices, services and resources between community members. The latter feature is essential to achieve our overall goal, i.e. the integration of pervasive and social computing. Note that we use the term integration to denote the application of social computing concepts in CSSs, e.g. the inclusion of advanced interaction forms. We do not intend to extend existing social media with pervasive computing capabilities. Finally, we foresee that smart capabilities can be brought into communities themselves and their management. For instance, communities may be automatically or semi-automatically created, extended or rearranged based on context information.

Selecting disaster assessment as a case

Pervasive collaboration tools that support information acquisition, information exchange and human collaborations have the potential to increase the efficiency and effectiveness of rescue teams in disaster management while reducing their personal risks. Today, a number of technical tools, such as computers, sensors, cameras and ad-hoc networking equipment, are regularly operated by rescuers in disaster areas. In effect, these tools already provide basic functionality for smart spaces. The CSS concept goes a step further. CSS aims at bridging the isolated smart spaces, enabling for dynamic grouping of helpers and corresponding information exchange and collaboration.

The collaboration between experts in cooperation with volunteers can also be of great help. Recent studies have discussed the involvement of the crowd through social networks in disaster situations. For instance, Twitter has been used by people outside disaster areas to provide information relevant for people affected by a crisis (Sutton, 2010; Hughes and Pallen, 2009). However, Reuter, Marx and Pipek (2011) point out that it is difficult for disaster management teams to obtain the information they need to make decisions and that they lack an infrastructure for collaboration between these teams and the crowd. Rather than addressing the extraction of information from existing social networks, we concentrate on cooperating with offsite volunteers for specific tasks. While we apply the CSS concept to create a platform targeted to rescue teams, we propose to exploit the configuration capabilities of smart spaces to facilitate the extension of the platform with services for cooperation with volunteers. Volunteers do not need to learn a new platform. Instead the services for cooperation can be provided as web services or apps in popular social networks.

Disaster management includes a number of activities involving actors with different needs. For our study we have chosen to focus on disaster assessment, i.e. the activities that take place directly after a disaster has occurred with the aim to assess the needs for support in an affected country or region. The user evaluation presented in this paper has involved experts recruited at the Assessment Mission Courses (AMC) of the European Civil Protection Mechanism. The AMC simulates a disaster scenario consisting of an earthquake with resulting damages to the local infrastructure and casualties in the population. During the course, the participants from several countries learn how to assess the situation after a disaster in a foreign country, and how to use the technology they have available for this.

RELATED WORK

The technologies needed to realize the vision of pervasive computing have notably matured. This includes wearable and handheld computers, wireless communication, sensors, etc. Disaster management is a relevant application domain where the technology can support the rapid and accurate collection of data, efficient decision-making, and situational awareness and individual guidance (Lukowicz, Baker and Paradiso, 2010). Rather than developing new sensor and communication technologies, our work addresses the flexible setup of smart spaces, the sharing of data and devices in communities and the development of community-based services that exploit these sharing capabilities.

Social computing is about supporting online social interaction. The core ideas of social computing date back to the 60's with the introduction of the computer as a communication device and have evolved towards more advanced and focused forms of interactions, such as computer-supported collaborative work (CSCW). Social computing has gained increasing popularity with the introduction of social networks and micro-blogging. Our work exploits the knowledge acquired in the area of CSCW to support focused collaboration within communities of assessment experts. It also exploits the social graph and activity feed concepts that were introduced into social networks for community management and communication. In addition, it extends social networks with the capability to share devices and services in communities.

As pointed out by Palen and Liu (2007), strong involvement of the public in disaster situations is not new, but information technology enlarges the scope of participation. For instance, the support of the crowd using social media has shown to be useful to collect and process raw information in order to bring support to the victims (Sutton, 2010; Hughes and Pallen, 2009). Differently from these research works that focus on information gathering, we propose to involve volunteers in specific tasks, e.g. map tagging or translation support. The introduction of the hashtag-based syntax Tweak the Tweet (TtT) after the 2010 Haiti earthquake and its rapid adoption by twitterers around the world (Starbird and Palen, 2011) exemplifies the potential of simple tools and the willingness of volunteers to adopt these tools. In our case, services for cooperation will be provided to volunteers as simple web services. The trustworthiness of the information provided by the crowd is often questioned. Vieweg et al. (2008) observe that the collective intelligence helps protect from the spread of erroneous information. However, we consider this to be an unresolved issue and the search for mechanisms to achieve trustworthiness has high priority in our work.

RESEARCH APPROACH

Our research follows the design-science paradigm (Hevner, March and Jinsoo, 2004). While behavioural-science approaches focus on the use and benefits of a system implemented in an organization, design-science approaches seek to create information systems to solve identified organizational problems. Design-science approaches follow a recursive process allowing a gradual understanding of the problem to be solved and the improvement of solutions. The creation and assessment of IT artefacts is central for understanding and improvement. The term IT artefact is used in a wide sense and denotes various items related to the creation of information systems, such as models, methods and software prototypes. The design-science paradigm does not impose any concrete research and evaluation method. Different methods can be applied depending on the nature of the problem to be solved and the type of IT-artefact being created.

As a first step in our research, we have focused on: a) gaining a better understanding of current practice with regard to information management and collaboration in disaster assessment; and b) concretizing the CSS concept to support collaboration between users. To that end, we have adopted the scenario-based approach proposed by Rosson and Caroll (2002). The primary IT artefact is thus a scenario, illustrating the application of the CSS to disaster assessment. This scenario was iteratively refined, through several participatory and evaluation techniques. The construction of a scenario requires the knowledge of current practice. A disaster management field study was conducted during the Assessment Mission Course (AMC) in November 2010 in Cyprus, where participants, the environment and tasks were closely observed. Experienced disaster management experts were also consulted, through participatory discussions. In addition, a small sample of experts took part in an online survey that captured information about their experiences with mobile, pervasive and social technologies. Exploiting these results, a refined scenario script was composed and developed into an interactive storyboard, which was in turn used at a later AMC course in April 2011, to capture participants' evaluations of the proposed novel technologies, in a paper trial. More details can be found in (Jennings, 2011).

CURRENT DISASTER MANAGEMENT ASSESSMENT PRACTICE

The user community involved in our field study consists of disaster assessment experts who participate in international disaster relief missions. They form a very strong community: the number of persons involved in this field is limited, they meet each other on different trainings, and they have often worked together under very intense, sometimes even traumatic conditions. The European Commission has established a curriculum of courses designed to qualify disaster management experts for disaster assessment. Some key observations collected during the field study at the AMC course in November 2010 are:

- *Organisation in teams*. Participants work in international teams that are composed to distribute workload and combine expertise. Although originating from different countries and professional backgrounds, team members are required to rapidly cooperate and communicate effectively. Responsibilities within a team (driver, navigator, team lead, safety & security, media handling) are assigned based on previous experience and training. One person often has responsibility for several roles.
- *Information flows and decision-making*. Participants struggle to cope with the pace of events and the large amount of information they are required to manage. They often lack crucial background information for a task at hand and need to improvise. Tasks require teams to span a wide field of expertise and cope with unforeseeable situ*ations*.
- *High workload and time pressure*. Participants are expected to coordinate their tasks and appointments with time constraints and across a large spatial spread. Teams often have significant problems navigating by car in a foreign environment under time pressure. They often have problems making proper introductory statements due to their stress levels. In addition, they have to meet reporting deadlines (e.g. 16:00, Brussels time).
- *Changing working environments*. Participants are intermittently sitting in very concise meetings, then on the move. Teams mostly discuss matters, make decisions and organize their information while they are on the move, i.e. in the car.
- *Technical concerns*. Participants are challenged by taking care of their equipment, including the electronic equipment.

EARTHQUAKE INTERNATIONAL RESPONSE SCENARIO

The scenario developed for exploration and evaluation of the CSS concept illustrates a disaster assessment after the occurrence of an earthquake in Cyprus. International rescue teams, e.g. for Urban Search And Rescue (USAR), have been sent to Cyprus to support the local emergency management. Each team member is equipped with a CSS-enabled toolkit that includes information about the user and supports smart space interaction and collaboration. The CSS community orchestration mechanisms have helped to assemble the rescue teams as fast as possible, matching the assessed requirements with the team members' expertise and availability. In order to rapidly map the situation, a request to volunteers was sent to mark unblocked streets or destroyed infrastructure on satellite-gathered pictures. The results are then made available to the rescue teams through their CSS. The USAR teams' task is to assess the buildings that are partially destroyed and rescue trapped people. A communication network is set up as the first step toward deploying a sensor network and relaying data. Wearable sensors support rescuers in collecting measurements and logging activities that are first shared with a mission controller for assessment, and then shared with all community members. The rescuers can also "geo-tag" their exact positions and "audio-tag" the situation. The global coordination centre makes use of volunteers to transcribe audio into text. The transcribed texts are later attached to the situation report made available to the rescue communities. Volunteers can also be involved in specialised tasks. For instance, members in the Unmanned Aerial Vehicle (UAV) community may be requested for flying assistance during the inspection of the structure of a dam. At the end of a shift, teams get support from the CSS platform to get connected to the next team and to transfer assessed information. In emergency cases that require team reallocation, the On-Site Operations Coordination Centre (OSOCC) can base their decisions on the logged activity data stored by the CSSs.

PAPER TRIAL

To evaluate the proposed CSS concept, a storyboard based on the scenario was developed using the visualisation and presentation tool Prezi. A storyboard is "*a short graphical depiction of a narrative*" (Truong, Hayes and Abowd, 2006) making textual scenario narratives more readily accessible to the users. This fits well in the context of pervasive computing that has a strong requirement for contextual storytelling (Dow, Saponas, Li and Landay, 2006) rather than focusing on system interactions, as served by traditional paper prototyping. The storyboard evaluation sessions were facilitated at an AMC course in Cyprus, in April 2011, with four small groups of disaster management experts; fifteen particpants in total. Each evaluation was structured into two parts: a storyboard presentation with embedded multiple choice questions, which participants answered individually; followed by a facilitated open discussion where experts shared their insights and gave feedback. The main findings are summarized below. More details can be found in (Jennings, 2011).

- *Community Orchestration, Team Prioritisation and Automation*. Participants were familiar with concepts like sensor technologies and crowd sourcing, but it was not so clear for them how a system could make intelligent decisions. Some participants did not believe a computer system would be capable of managing team prioritisation and task allocation as well as humans, due to the complex human factors such as psychology, chemistry and trust, which are difficult to measure. However they could see potential value in a system making intelligent suggestions.
- *Access to better information*. The participants could see a clear use for more information, and were very positive in being able to access expert insights, sharing satellite maps and overview information.
- *Information flows*. Most participants were familiar with sharing GPS coordinates for location, but made a distinction between retaining control in sharing this information, sharing it continuously, or making it available on demand. They also clearly distinguished between sharing publicly, within a team and with the OSOCC. There was much disagreement among participants about sharing personal data collected by sensors.
- *Crowd sourcing, Collective Intelligence, Trust*. The participants recognised the value in having access to the "wisdom of the crowd" for assisting with some simple tasks or technical expertise. However, most participants had reservations about information from untrained or unknown sources. Some participants suggested that conditions, such as crosschecking or traceability, should be met before information is accepted. A clear support was given for prioritising crowd-sourced information from trained and registered volunteers, particularly those who are traceable through existing trusted organisations (such as the Red Cross).
- *Translation Services*. Almost all participants agreed that translation constraints hinder relief efforts by slowing down emergency responses in a disaster situation. There was a broad acceptance for the usefulness of a translation service. However, they voiced a preference for a human guide, who could also interpret local cultural and geographical signs.

- *Remote Distribution of Administrative Tasks*. While some participants saw great value in relieving first responders by assigning administrative tasks to offsite volunteers, another participant was sceptical about it, and had concerns about the security of sensitive data. A strong potential value was recognised in allocating specialised tasks to offsite experts.
- *Privacy*. In general the monitoring of individuals was not viewed favourably. Several participants feared that the proposed system could introduce close monitoring akin to the "Big Brother" Panopticon. However, the sharing of internal information within a team was accepted when it benefited team health and safety.
- *Security*. Some data is confidential and should probably not be recorded at all. The participants identified a potential risk for the safety of personnel or affected persons if disaster situation data is not managed in a secure way, for example, the disclosure of sensitive geo-locations in a humanitarian mission.
- *Setting up and managing a smart space*. Most participants were willing to wear small devices that improve communication in the field. The majority of participants could see the benefit of spending time establishing networks, but few of them were interested in maintaining devices in the field.
- *Usability*. In general, the participants accept the improvements provided by the proposed CSS features. However, they emphasize that the system should be unobtrusive, user-friendly and easy to manage.

CONCLUSION

The evaluation results have important implications for the design of the CSS platform. In particular, the rescuers ask for control of: a) the management of communities, i.e. a manual composition of teams is preferred; and b) the sharing of information within and across communities. At the same time, they are concerned that the system configuration may introduce additional user effort. We will therefore seek to provide user interfaces that naturally extend user behaviour in the working environment. Finally, the inclusion of an offsite volunteer community requires special attention to ensure: privacy protection for rescuers and affected persons; and the trustworthiness of the volunteers' contributions. The realisation of a first prototype for a user trial in Autumn 2012 is currently ongoing. We intend to refine this prototype with the help of the users, through for example participatory design, towards a second user trial end of 2013.

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