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Deliverable D5

Escritoire2 Project: Conclusions and Future Work

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Contents

1 Project summary

This is the fifth and final deliverable for Marie Curie Outgoing International Fellowship project 21743, “Distributed Crisis Management Using Remote Collaboration Technologies”. The previous four deliverables, D1–D4 (Ashdown, 2007, 2008b, 2008a, 2009), respectively correspond to the four subsections below. Those four cover the domain analysis for urban search and rescue, implementation of the remote collaboration system, experiments to investigate how people use the system, and the results of the experiments. This deliverable, D5, summarizes the whole project and describes directions for future work.

In this project we have implemented and experimented with a remote collaboration system designed for emergency response. The aim of our system is to improve the process and product of team co-ordination, particularly in emergency response, by providing collaboration support that is richer than a standard voice channel. Sharing of information in this domain still relies solely on basic voice communication for all remote communication. There is potential for improving team co-ordination through sharing of information. For example, misconceptions of location in emergency response have had devastating consequences (Schoning, Rohs, Kruger, & Stasch, 2008), so sharing maps to improve communication about locations and directions should provide important benefits.

1.1 Domain analysis

We chose urban search and rescue (USAR) as the application domain for this project, although the principles should be applicable to many similar domains such as other types of emergency response, and military command and control.

Typically organizations with a command hierarchy are divided into strategic, tactical, and operational levels. In this project we considered communication between a tactical actor in a command centre, and operational actors in the field. The different work styles, physical situations, and technological support for these roles means that collaboration between them will be very asymmetric, as described in D1 (Table 1, page 5), and a collaborative system for them should reflect this. The Incident Command System (ICS) (Bigley & Roberts, 2001), a popular standard for the command structure of such organizations, defines a span of control of seven, so we have assumed that the tactical actor will be co-ordinating up to seven operational units.

We performed a cognitive task analysis (CTA) on the search, rescue, and tactical roles in a USAR team (D1, Section 3.3). Event flow diagrams and decision ladders represented the states and decisions of a search team leader and a tactical actor. Basically, the tactical actor alternates between scheduling tasks and guiding search units. The search unt alternates between searching sites and navigating between them.

The CTA resulted in system requirements for supporting the situation awareness of the users, where situation awareness is defined as the perception, comprehension, and projection (Endsley, 1995) of the situation that is being monitored. It also resulted in information and function requirements. These requirements were used as a basis for designing a collaborative computer system that supports USAR operations.

1.2 Implementation

To support the work of the USAR team we decided to create a system for sharing visual information between team members. This complements the existing voice channel, providing common ground for the conversation. The shared workspaces also have workspace awareness features (D1, p14) to support synchronous collaboration that is as closely coupled as possible, thus differentiating it from existing systems for sending asynchronous messages between mobile devices.

In the command centre a tabletop display can be used. We opted for the largest and highest resolution display that we could, anticipating the type of hardware that will be available in future, based on the significant research interest in recent years on tabletop displays. The tabletop is based on Escritoire (Ashdown & Robinson, 2005) and T3 (Tuddenham & Robinson, 2007). The operational actor in the field must use a small handheld device, and we have opted for a device with touch input and screen covering its front side, which has become a popular design for mobile phones in recent years following the Apple iPhone.

The tabletop and handheld devices are linked together to allow remote collaboration. Their vastly different sizes mean they cannot simply show the same information, but we would like to tend towards What-You-See-Is-What-I-See (WYSIWIS) because this will provide a better grounding for closely-coupled collaboration. The difference in display sizes, together with other differences including the roles of the users, and their physical situations, have led to a form of asymmetric collaboration using relaxed WYSIWIS.

Deliverable D2 describes our design of a set of shared workspaces for asymmetric collaboration that are tailored to the USAR mission that was previously analyzed. The shared maps are an obvious requirement, The timeline is a new design that was refined following usability evaluation, and the report forms are based on USAR procedures described in Federal Emergency Management Agency (FEMA) documents and from talking directly to members of Hampshire Fire and Rescue Service. The workspaces have workspace awareness features designed specifically to support closely-coupled work (D2, Section 2.1 and 2.2).

In implementing the remote collaboration we have created a software system, which is described in D2 (Figure 10, page 12). This has led to further ideas on the technical aspects of networking and services for sharing information. Support for sharing data and events for synchronous collaboration will be developed as further work.

As part of the USAR scenario, we have also created an urban environment using Risk, a 3D environment simulator made by D-CIS.[1] This has been used in several experiments.

1.3 Experiments

We designed experiments to test the remote collaboration system, and in particular the effect of the workspace awareness features. Deliverable D3, Section 2, lists the research questions. The main ones are:

1. Does the system have the right features necessary for the team to co-ordinate their task?
2. Do the synchronous workspace awareness features lead to improvements?
3. How do collaborators handle the asymmetry?

The independent variable in the experiments was the presence of the workspace awareness features. There are two conditions: with and without the features. Various quantitative and qualitative measurements were made, including preference for the two conditions, a range of multiple-choice questions, counts of the number and type of utterances, lists of the strategies used by participants, and open-ended responses to questionnaires.

The main experiment used pairs of participants acting as a USAR team consisting of a tactical actor, a search unit, and a simulated rescue unit. The mission was to find and search buildings, and report on the buildings and any victims found. 13 teams of two people participated in these experiments (26 people in total). There were also two further experiments, as described in D4, Section 1.1. The first used three-person USAR teams, which had two search units in each team. Two teams participated. In the second, teams of two people were given the task of navigating along a route in an urban environment and checking it for security threats. The person using the handheld was guided along the route by the one at the tabletop. Three teams participated in this experiment.

1.4 Results

The results of the experiments are described in deliverable D4. Participants preferred to have the workspaces awareness features (WAF) enabled for the shared map. They also preferred to have them enabled for the reports in the two-person teams, but not in the three-person teams. This is

[1] http://www.decis.nl/

probably because in the larger team the search units needed to be more independent, and did not collaborate on entering reports as they did in the two-person case. There was no preference either way for the timeline. The WAF made no difference to performance, but they did cause more deictic gesturing.

Various strategies were used by the participants for completing reports, and for specifying locations on the map. For the three-person teams, the list of strategies used for reports was more constrained, again due to the independence required by the search units. Generally, speech became more concise, and concentrated on deviations from the norm rather than giving updates on everything that happened.

Mode confusion and the toolbar being out of view were problems on the tabletop display, and sketch input for manipulating the map was a problem, particularly when the user was under time pressure. Handedness was an issue that should be considered more carefully. The over-the-shoulder view was useful, but should perhaps be read-only to avoid problems caused by concurrent access. The visibility regions on the shared workspaces were useful, but added clutter. Some participants would have appreciated extra cues including audio cues, and also tactile cues (vibration) on the handheld, to draw their attention to changes that might require them to act.

Some participants requested a heading-up map rather than the north-up map that they were given. We chose north-up because this ensured all participants maintained the same orientation for their maps, thus preserving the WYSIWIS property. Brake and Kleij (2008) found that the choice between heading-up and north-up maps made no difference to satisfaction or performance in their experiment, and we think that in our case the tradeoff is in favour of north-up. Drawing and writing on the map sometimes become cumbersome, and drag-and-drop symbols tailored for the scenario would have been helpful, particularly on the handheld where any kind of drawing is difficult.

Preliminary results from a conversation analysis of the guiding task revealed a problem with occlusion on the projected displays that was not caught by the questionnaire responses or retrospective reviews.

2 Future work

We are currently investigating various options for future work, based on this project.

2.1 Online mapping

The shared map in the current system is web-based, and could be replaced by some other web-based system. Thales Research and Technology (TRT), the European host for this project, has a situation awareness tool for mapping of emergency incidents that could be used as the shared map in our collaborative system. The challenge will be to make the features of this tool usable not only on the tabletop, but also on the handheld. The feature support could be asymmetric, with more powerful features only available on the tabletop.

2.2 Transcoding and gateways

If many devices were to be connected together in a large emergency response organization, there would be a collection of heterogeneous devices, and network links of different types: some fast cable links, and some more restricted wireless links. Audio and video distribution over this type of network could be handled in an efficient and scalable way using content adaptation techniques such as those developed in the Visnet network of excellence, [2] of which TRT is a member. Similar transformation and encoding may be possible on the non-audio-visual data that must be shared between devices. The methods for doing this are open to future work.

[2] http://www.visnet-noe.org/

2.3 Combination with Nuva

TRT has a remote collaboration product called Nuva, which combines videoconferencing with document and application sharing. Our asymmetric USAR system could be combined with this, to combine the team-coordination features of the USAR system with the more office-oriented features of Nuva. Linking handheld devices to a fixed location for synchronous sharing of information could be very useful in many types of business setting.

2.4 Mobile phone implementation

For our current implementation we have used Sony Vaio UX computers as the handheld devices. They are essentially small laptop computers, running Windows Vista, and they have a touchscreen that simply emulates standard mouse input. These devices have been convenient for development because they do not require any special software. However, a more realistic implementation would result from using one of the touchscreen mobile phones with satellite positioning that have become popular in the last few years. In particular, a phone running the Android OS[3] could provide a powerful platform for deploying our system on a larger scale, because it is becoming available on various mobile phone handsets, and it supports the type of touchscreen interface that we have demonstrated on the handheld device. Implementation on an Apple iPhone is also an option.

2.5 Drag-and-drop icons

Free-form sketching should be kept as a feature of the the map, to allow for unforeseen events, but annotation of the map would be greatly enhanced by adding drag-and-drop icons for common items. This would be particularly useful on devices with touch input, because drawing accurately is very difficult using a finger rather than a pen.

A predefined list of symbols is required. One such list, made for emergency response, has been published by the Homeland Security Working Group.[4] Examples of symbols from that list are shown in Figure 1.

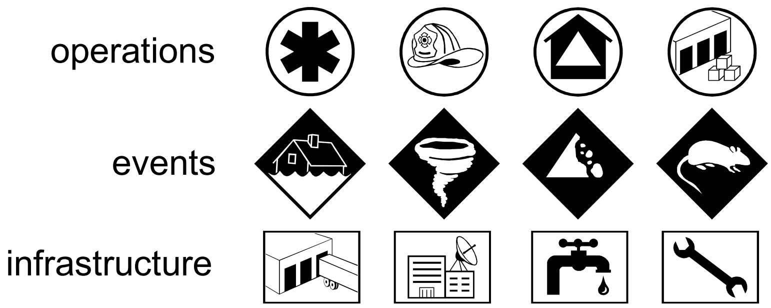

Figure 1: Map symbology. Circles denote operations, diamonds events, and rectangles infrastructure. This figure is duplicated from Deliverable D2, Figure 4, page 6.

3 Enabling technology

The sections below list various enablers for the type of remote collaboration system that has been prototyped in this project. Rather than direct future work, they are parallel developments that will effect future systems.

[3] http://www.android.com/
[4] http://www.fgdc.gov/HSWG/index.html

3.1 Reliable wireless networks

When measuring networks, people tend to focus on capacity in terms of megabits per second, but for this type of synchronous collaboration with workspace awareness, latency and reliability are more important factors. Existing digital standards for voice communications may have enough spare capacity to carry the data to enable workspace awareness features in shared workspaces, if latency close to that of the voice channel is achievable. Therefore, one way to enable sharing of visual data to personnel in the field is to develop a way to fit the required data into existing digital links. A challenge for existing networks is the reliability. WiFi (IEEE 802.11 networking) is common in homes and offices, but it cannot be relied upon in emergency situations.

3.2 Quality of service

For future networks, quality of service should be considered, not just for voice and video as is customary, but also for general data streams. Various levels of service should be available, to differentiate latency-sensitive data, such as those to control telepointers, from less sensitive data, such as image files that are being downloaded for later viewing. Telepointers could be sent as high priority, sequenced data (only the latest data is needed), whereas map tiles could be sent as low priority, reliable data (retransmission is applied automatically).

3.3 Handheld and tabletop hardware

To provide the asymmetric remote collaboration system developed for this project as an actual product, suitable handheld and tabletop displays are required at a reasonable price.

The handheld devices, in the form of mobile phones, are available now. The processing power, memory, storage, satellite tracking, high-resolution displays, and touch input required for this application are all available in consumer products, thanks to mass production driven by consumer demand for advanced devices. Moreover, various tablet-sized devices with pen and touch input are due to be brought to mass-market production in the next year or two. These could fulfill a similar role, while somewhat relaxing the space constraint on the handheld display.

Development of tabletop displays has been progressing since their inception almost 20 years ago. They are now available to buy as complete units, but the price is still too high, and they are too unwieldy to install in many environments. Continuing advancements in displays—particularly organic LEDs—and touch and pen input should yield tabletop displays as off-the-shelf products for installation in command centres in five to ten years.

3.4 Cognitive task analysis

In the initial domain-analysis phase of this project, we found the application of event flow diagrams (D1, Section 3.3.2) to be somewhat contrived at times, because it can force the assumption of either an event-driven system (where transitions are triggered by asynchronous events) or a process-driven system (where a transition occurs whenever a task is completed), when in fact a system may have properties of both types. Also, the dichotomy between the high-level event flow diagrams, and the low-level decision ladders can be somewhat artificial. The operator function model (OFM) (Lee & Sanquist, 2000) may be better. In OFM, a process is represented as a finite state automation, and depicted as a graph with vertices for the states and labelled edges for the transition conditions. OFM naturally decomposes to handle different levels of abstraction, and like the CTA method we used for this project, it can be augmented with descriptions of cognitive tasks and the resulting information and function requirements for technological support.

4 Conclusion

The increasing capacity and coverage of wireless networks means that more advanced forms of communication are becoming feasible for distributed teams. One way to use the extra capacity is to add video cameras to the conventional voice channel of the telephone, but despite its intuitive appeal this has not proved popular. Current mobile devices still support synchronous communication almost exclusively with voice, but we believe there is great potential for synchronous collaboration over visual information.

Advances in small and large interactive devices are prompting many developments in human-computer interaction. Portable touchscreen devices are providing much richer interactive experiences on mobile phones. Tabletop displays are providing a new type of experience for fixed locations that is particularly suited to visualizing large amounts of information. These devices at the two ends of the size scale enable a new kind of asymmetric collaboration.

In this project we have explored how asymmetric synchronous collaboration can be used to support the work of distributed teams, with a particular focus on urban search and rescue. This has led to various insights into the technological and interface design issues, and we will be pursuing these further in future.

4.1 Acknowledgements

Prof Chris Firth at Thales and Prof Mary (Missy) Cummings at MIT, as the scientists in charge at the two host organisations, have steered this project from the beginning, and provided valuable help along the way.

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References

Ashdown, M. (2007, October). *Asymmetric distributed collaboration in emergency response.* (Deliverable D1 of EC Marie Curie OIF project 21743)

Ashdown, M. (2008a, September). *Design of experiments for asymmetric distributed collaboration.* (Deliverable D3 of EC Marie Curie OIF project 21743)

Ashdown, M. (2008b, March). *Implementation of asymmetric distributed collaboration.* (Deliverable D2 of EC Marie Curie OIF project 21743)

Ashdown, M. (2009, April). *User experiences with asymmetric distributed collaboration.* (Deliverable D4 of EC Marie Curie OIF project 21743)

Ashdown, M., & Robinson, P. (2005). Escritoire: A personal projected display. *IEEE Multimedia*, *12*(1), 34–42.

Bigley, G. A., & Roberts, K. H. (2001). The Incident Command System: High-Reliability Organizing for Complex and Volatile Task Environments. *Academy of Management Journal*, *44*(6), 1281–1299.

Brake, G. te, & Kleij, R. van der. (2008). Distributed Mobile Teams: Effects of Connectivity and Map Orientation on Teamwork. In *Proceedings of ISCRAM 2008* (pp. 642–650).

Endsley, M. R. (1995). Toward a Theory of Situation Awareness in Dynamic Systems. *Human Factors*, *37*(1).

Lee, J., & Sanquist, T. (2000). Augmenting the operator function model with cognitive operations: Assessing the cognitive demands of technological innovation in ship navigation. *IEEE Transactions on Systems, Man, and Cybernetics, Part A: Systems and Humans*, *30*(3), 273–285.

Schoning, J., Rohs, M., Kruger, A., & Stasch, C. (2008). Improving the Communication of Spatial Information in Crisis Response by Combining Paper Maps and Mobile Devices. In *Proceedings of Mobile Response 2008.*

Tuddenham, P., & Robinson, P. (2007). T3: Rapid Prototyping of High-Resolution and Mixed-Presence Tabletop Applications. In *Proc. IEEE TABLETOP 2007.*