When and how (not) to trust IT? Supporting virtual emergency teamwork

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ABSTRACT

In this paper we use the formative evaluation of a prototype 'assembly' of pervasive computing technologies to specify design implications for emergency virtual teamwork tools. The prototype assembly, called "*Overview*", was implemented in collaboration with police, fire and medical emergency services as part of the real life event management during the Tall Ships' Races 2007 in Denmark. We describe how the emergency teams used the technologies for collaboration between distributed colleagues, to produce shared situation awareness, to manage efforts and resources and respond to minor emergencies. Trust in technology is a key need virtual teams identify in their endeavours to dovetail innovative technologies into emergency work. We show how practices of working up trust are supported by the PalCom open architecture (which was used to build *Overview*), and delineate design guidelines to enable the productive integration of pervasive computing.

Keywords

Virtual teams, trust in technology, palpable computing, participatory design.

INTRODUCTION

Pervasive computing technologies have great potential to augment the work of distributed 'virtual' emergency teams. Experimental R&D shows that interactive maps, mobile and wearable devices, sensor-networks, location tracking, and ambient technologies (e.g. CCTV) could support en route sense-making (Landgren 2005), risk assessment, resource allocation and communication (Jiang, Hong, Takayama, Landay 2004), reasoning about conditions on the ground (Betts, Mah, Papasin, del Mundo, McIntosh, Jorgensen 2005), reconnaissance and navigation (Denef, Ramirez, Dyrks, Stevens 2008), and in-field patient triage and tracking (Lorincz, Malan, Fulford-Jones, Nawoj, Clavel, Shnayder, Mainland, Welsh, Moulton 2004). However, in practice, the potential of pervasive computing is hard to unlock. Erika Frichshnecht Christensen, Medical Director of Pre-hospital care, Central Denmark Region, pinpoints why:

> *"… everybody talks about wireless monitoring, but I haven't seen it work so far. I think one of the things is … how do I identify the patients, am I sure that what I see on the screen is actually that patient and not that patient?"* (Discussion, December 2007)

Frichshnecht identifies a key need virtual teams encounter in dovetailing innovative technologies into safe emergency work practices: People must be able to trust their technologies.

This is a 'Catch 22' challenge. Trust in technology is 'accepted dependability' (Avizienis, Laprie, Randell, Landwehr 2004). It grows as technologies become more dependable and familiar, but to become dependable and familiar technologies must be tested in use when they cannot (yet) be trusted. This is particularly difficult in emergency work, where only controlled leaps of faith, combining 'graceful augmentation' (Jul 2007) with safe levels of redundancy in experimental but realistic use of new technologies will allow innovations to be adopted. This strategy is currently ill supported by many pervasive computing technologies.

In his pioneering vision for 'ubiquitous' computing, it was Mark Weiser's 'highest ideal to make a computer so imbedded, so fitting, so natural, that we use it without even thinking about it." (http://www.ubiq.com/ubicomp/). Weiser's call to make the computer 'invisible' has been enthusiastically interpreted, most often literally. For all the right reasons – e.g. to protect responders from additional work and complexity overload – designers seek to hide computing by embedding it in devices, environments (Lorincz et al 2004), even clothing (Rantanen, Impiö, Karinsalo, Malmivaara, Reho, Tasanen, Vanhala 2002), by making it 'autonomous' (Fiedrich 2000), self-healing, and context-aware (Lorincz et al 2004). While we value the power of these approaches, we also believe that they can – paradoxically – hamper what they seek to support. This is because Weiser's main concern was not invisibility *per se*, but 'invisibility-in-use', synonymous with the phenomenological notion of 'ready-to-hand', meaning that users are able to focus on their work rather than on their technologies. In this process, trust is not a state of mind, or once-and-for-all accepted dependability, but an ongoing practical achievement. Just as people come to trust other people because they continuously (often precognitively) observe and probe their behaviour in different situations (Boden and Molotch 1994), people work up trust in technologies through ongoing practical engagement with them (Clarke, Hardstone, Rouncefield, Sommerville 2006). However, if the technologies are designed to hide their states and processes, people have no basis on which to build their trust. In a conceptual framework for 'palpable computing' we argue that in order to understand and trust technologies people must be able to sense what these technologies are doing or could do for them (Kyng 2007). To this aim, we have developed an open software architecture and prototype technologies that support people in making computing palpable (Andersen 2007).

In what follows, we describe a key stage in this endeavour: the experimental deployment of a prototype assembly of pervasive computing technologies – the *'Overview'* – during the Tall Ships' Races 2007 (TSR), in Aarhus, Denmark. In collaboration with police, fire and medical emergency services we enabled the flexible integration and interrogation of existing and prototypical pervasive computing technologies as part of the real life event management, utilizing the PalCom open architecture. The main purpose was to evaluate a) the usefulness of *Overview*, and b) the usefulness of the PalCom architecture. When, and more practically *how*, (not) to trust the technologies emerged as a crucial issue for end users and developers. We discuss how the emergency virtual teams used the technologies for collaboration between distributed colleagues, to produce shared situation awareness, to manage efforts and resources and respond to minor emergencies. Our three examples show how trust in technologies was practically achieved and provide important lessons for design. To sum up, we describe three key implications for design and argue that attention to these challenges could facilitate the productive integration of pervasive computing technologies in emergency virtual teamwork.

BACKGROUND

Design for palpability and trust demands a fundamental re-orientation of pervasive computing principles and this is our primary concern. But such 'large' design aims are best achieved through ethnographically informed, experimental and iterative participatory design (Büscher 2006, Kristensen, Kyng, Palen, 2006, Büscher, Kristensen, Mogensen, 2007). In a 4 year research project called PalCom (http://ist-palcom.org) we have used a nested participatory design approach, developing a range of pervasive computing application prototypes as a vehicle for the design of more fundamental architectural support (Büscher, Christensen, Hansen, Mogensen, Shapiro 2008). *Overview* has been developed close to 'product stage', aimed to support emergency responders, and through its experimental deployment during TSR we explore key use requirements in emergency virtual teamwork. Apart from trust in technology, the most significant problems – and opportunities – for design that this long-term collaboration with first responders has identified centre on:

Collaboration, coordination and improvisation. Crises require collaboration and unified management, but make their ongoing achievement difficult (Wachtendorf, Kendra 2005). The need to establish priorities through inter/intra-organizational communication is often frustrated through disrupted or inoperable communication infrastructures (The White House 2006). As these are patched with temporal solutions, interoperability and resilience become a concern. Speedy, reliable communication is also key to integrating capabilities provided by the military, volunteers, or the public (Palen, Liu 2007). Support for accountable and collaborative improvisation is lacking.

Overview and Situation awareness. The ability to gather and use reliable information to make decisions and project future developments is crucial for accurate overview, comprehension and communication of what has happened (Endsley, Bolté and Jones 2003). Speed is important, but appropriateness of response ranks even higher. First responders often receive multiple reports from several sources and experience complex 'symptoms' at multiple sites under great pressure to act immediately (Greater London Authority 2006, Martin and Bowers 1997). This hampers the production and communication of accurate assessments of the incident, its causes and unfolding effects.

Overview seeks to support collaboration, coordination, improvisation and the production of overview and shared situation awareness. The prototype and the set-up at TSR 2007 are described in the next section.

OVERVIEW AT THE TALL SHIPS' RACES 2007

From July 5th – 8th 2007 over 100 sailing ships docked in Aarhus harbour, before setting off for a race. Many were open to the ca. 500,000 people who attended the event. In addition, over 50 restaurants, bars, shops, and entertainments were set up in the 3 km^2 harbour area. *Overview* allows professionals to utilize pervasive computing devices and services to produce a dynamic overview of the situation on the ground. It integrates Topos™ with PalCom-enabled services, where PalCom-enabled means that resources utilize the PalCom open architecture (Andersen 2007) and can, therefore, be interrogated, inspected and combined with other PalCom services. Figure 1 shows an *Overview* screenshot one day before the start of the event.

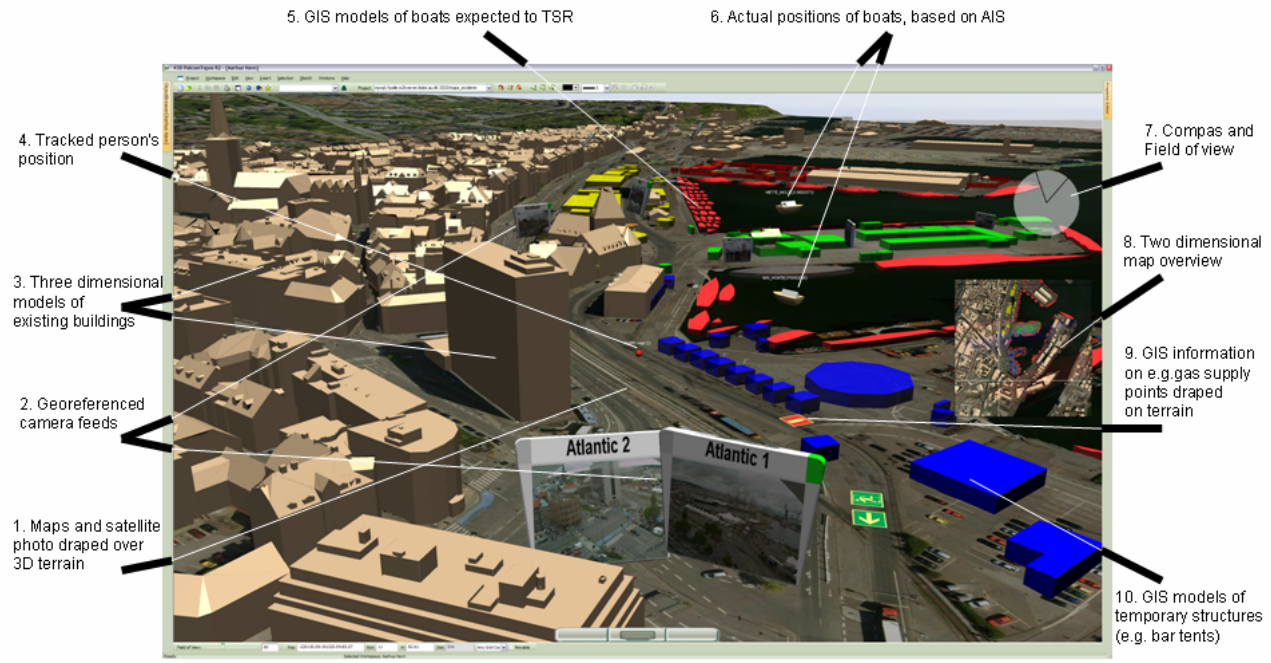

Figure 1: *Overview* display in Topos™ in 3D mode.

Satellite photography is draped over the 3D terrain (Figure 1, item 1), so that real surfaces, existing buildings and vegetation are visible. Users can switch GIS data draping and map overlays on or off (9). Models and GIS information for permanent and temporary structures are inserted (3, 10). A GIS inspector enables users to search tabular GIS information. The boat-shaped models (5) indicate where ships are supposed to dock. Live tracking of GPS positions of different resources (Automatic Identification Systems (AIS) (6), mobile phones (4), fire trucks or patrol vehicles), makes it possible to see the actual positions and movements of people and objects. In Figure 1, for example, two ships are arriving (6). Live streaming of video and still pictures taken by GPS tracked mobile phones are shown at geo-referenced positions (2). Users can sketch e.g. potential access routes, and a 2D map overview (8), where one's current position is marked, supports navigation.

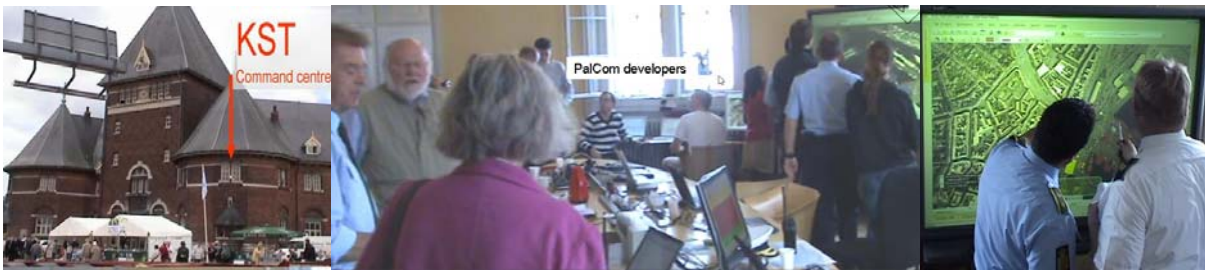

Figure 2: The command centre with *Overview* during TSR.

Overview devices and services were installed around the harbour. In the command centre, established in the strategically located old customs house, staff used Topos™ on a large interactive display (Figure 2), to view, discuss and interrogate data from external devices, including:

- five web cameras fixed onto high buildings
- a remotely controllable dome-camera fixed onto a corner of the main stage
- four Nokia N95 GPS enabled phones carried by different officers on patrol in the event area (Figure 3)
- one Nokia N95 phone carried by the rescue divers on their boat patrolling the harbour (Figure 3)
- more than 100 AIS transponders (existing, standard equipment on ships)

Figure 3: Tracked officer (Jens Fonseca) and tracked boat with rescue divers. Right: Pictures taken by patrol officers can be viewed in the context in which they were taken within the model.

Officers used the phones to photograph issues they wanted to report or discuss with colleagues in the command centre. Figure 3 shows pictures and their locations that were discussed in managing the event (see also Example 1). In addition to the devices directly used by the emergency personnel, three computers were used by developers to monitor the status of devices and services within *Overview* (seen in the background of Figure 2 above). ´

EXAMPLES OF USE AND EVALUATION

In this section we present three examples of how *Overview* and the PalCom open architecture were used during TSR. As part of long-term ethnographically informed participatory design process these technologies are designed to support collaboration, coordination, improvisation and the production of overview and shared situation awareness. In addition, they respond to the fact that in order to realize this potential, people need to be able to build trust in these technologies. This latter requirement is largely intuited by the researchers, but clearly important. Trust, like agreement in conversations, is often implicit. Explicit statements like Frichshnecht's are rare, especially when actually trying to use the technologies. Rather, trust (or distrust) is documented through continued (or discontinued) use. In the examples below we describe how trust in technologies was practically achieved and seek to draw out important lessons for design and implementation.

Example 1

This example explores how the personnel work to trust (or distrust) technologies: Christian, the fire service team leader, asks two patrol officers to carry one of the tracked Nokia phones. They receive less than one minute of instructions, during which a picture is taken, which duly shows up in Topos™ on the doorstep of the command centre (the last position recorded by the GPS, which only works outdoors). As the patrol set off, their movements are tracked. We see them at Pier Three, then, half an hour later, at Pier Two. Christian's mobile phone rings: the officers have spotted a car parked on an emergency access route. Christian asks them for the registration number. Writing it on a notepad, he asks them to take a picture, then shouts the registration number across the room to a police officer who begins a search on the police database to find the phone number of the car owner in order to get the car moved. Christian walks to the Topos™ screen, where Preben, one of the computer scientists, is demoing *Overview* to a visiting emergency chief. Christian asks: 'Preben can you find that picture that just came up?' (Figure 4). Preben, who had also been monitoring the patrol, notes a new picture along their path and opens it in its host application (Figure 4). He gives Christian time to see the registration number, before continuing the demo.

Figure 4: The patrol officers 'AABR-vagt' document a wrongly parked car.

Christian walks to the police desk. Looking at the police officer's note pad, Christian notes a mistake 'What have you written down here? XY? I think it's XP' (Figure 4.4). Preben overhears this and pulls the picture to the front (4.5), just as Christian says 'Isn't that right Preben?'. Preben reads the registration number out. The police officer re-enters the number in the database and now finds the owner's telephone number.

Lessons learned

The phones used at TSR often ran out of battery, which meant last known, 'frozen' positions were shown in Topos™. Everyone knew that the representations of positions should be regarded with healthy distrust. However, in the above example, Christian is evidently confident that all concerned are talking about the same car, whose actual position is known. A closer look reveals different methods in the ongoing working up of trust, including:

- triangulating shown positions with people's descriptions of where they were/are, (Christian knew from the phone conversation that the officers were on Pier Two)
- seeing the label, representing the phone, wobble (which it does due to fluctuations in GPS accuracy, even when the phone carried is not moved), which means that we are receiving live signals from it
- seeing the label move as the person carrying the phone moves
- seeing that the representation of the officers' position was close to where the new picture showed up
- noting that what is shown on the picture matches the reported position (a car next to a large ship, on a known emergency access route)
- knowing that developers are confident things are working

Any single one of these methods would not ensure that the reported positions were correct, but the different indications in combination provide Christian with sufficient assurance to trust that the technologies support accurate risk assessment and decisions about the parked car.

The PalCom open architecture supports the assembly of the GPS and the camera in the phones with services that display their output in a way that supports these methods and their combination (Andersen 2007, Kyng 2007). We call this support for *flexible redundancy*. As we will elaborate in Example 3, there are multiple layers of inspection. But the value of support for flexible redundancy also lies in the fact that, while it is obvious that the individual technologies' reliability could be substantially improved (e.g. through better batteries), with so many devices, services, connections, etc. in play, some of them will always fail. Multiple, flexible indicators are, therefore, crucial to allow people to combine different means of assessing the trustworthiness of the reported state of affairs.

Another important means for working up trust is *quick and implicit experimentation*. The rapid sequence of taking a test picture and seeing it appear in the expected position, before going out on the patrol, is one such experiment. It relies on – and documents – the functioning of *Overview*. Moreover, the *flexible interaction* with *Overview* provides means to ensure the different actors that they are assessing the situation correctly. Christian and Preben's ability to either open the image in its host application (Figure 4a.3), or bring the image to the front (Figure 4b.5), or go to the geo-positioned image of the issue at hand and see it in its context allows users to inspect data as part of different activities (enquiries into the matter, checking a detail, demo-ing). It does not by itself show how such small enquiries supported development of trust. However, throughout TSR innumerable such interaction experiments were carried out, and we observed how they fostered trust in, and ever more extensive use of, the technology.

Example 2

This example shows how multiple sources of situation accounts and technologically mediated evidence can support the production of situation awareness and collaborative accountable improvisation: 7:40 pm Saturday: Paul, an untracked fire service officer, calls: 'I'm behind the stage (marked X in Figure 5.1). It's chaos here. I need Jens'. People queuing for a concert are creating a dangerous situation, blocking vehicles from accessing the ferry port (5.2). Paul wants the duty police officer's (Jens') opinion. The call taker in the command centre – Peter – looks at *Overview* (5.1): 'Jens is on the corner of Pier Three, near you'. This completes the radio conversation and Paul goes looking for Jens. Meanwhile, the police commander, Amrik, has asked one of the developers, who is already looking at the concert area using the dome video camera mounted on the stage, to turn it to look at the entrance (5.3). As the camera reveals a view, Amrik says 'There's no pressure [no problem] here' (5.4). He asks the developer to switch to the camera overlooking the crossing close to the concert area (Sibirien) and remarks 'But they're queuing all the way down here,' (5). There is no camera with a view onto the ferry port access road. Now Paul calls again: 'I can't find Jens'. Amrik asks the developer 'Can I take over?' and switches to the 'home' position to see Jens' position (5.6). Peter looks at it and tells Paul: 'But he is there' (5.7). When Paul and Jens finally meet, Jens requests back-up, saying 'You know where I am', and they resolve the situation.

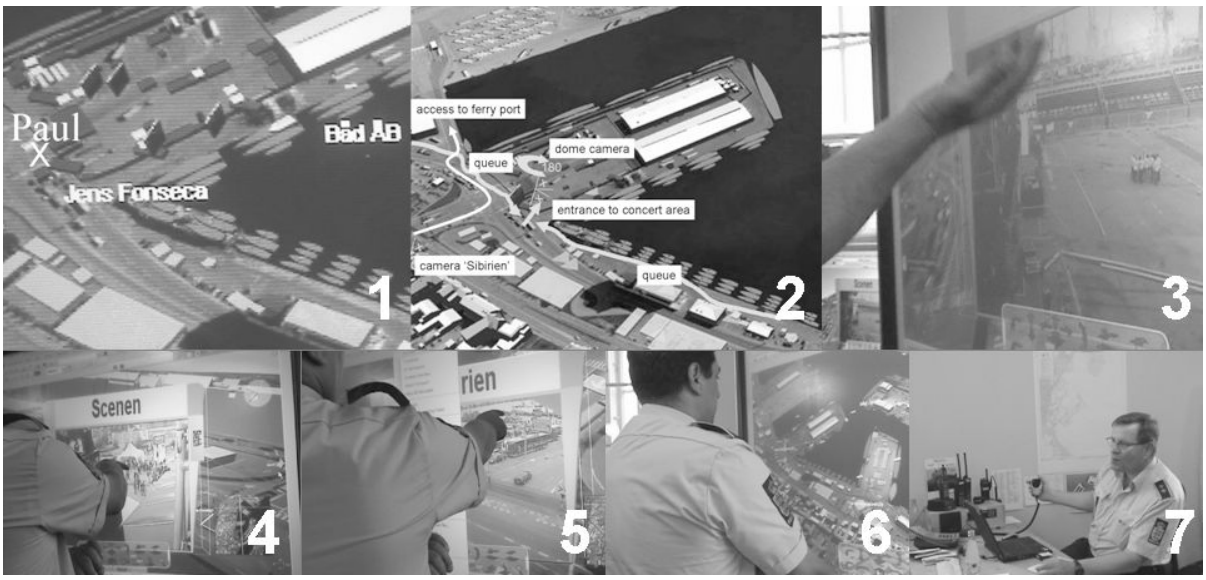

Figure 5: Producing situation awareness, assessing the risk of people queuing through radio, GPS, cameras.

Lessons learned

The use of *Overview* in this situation affords the emergence of new virtual teamwork practices. Paul, Peter, Amrik, and Jens are enabled to form a shared picture of the situation on the ground. Amrik initially treats Paul's report with scepticism, not because he does not trust Paul, but because he knows that being embroiled in a situation on the ground can make things look more dramatic than they are. He checks, making full use of the technology to inspect the trouble through evidence from different sources (radio report, map and model, two different camera angles) and leads the collaborative risk assessment and response. Such flexible access to *multiple sources of situational evidence* supports *distributed collaboration* in the production of situation awareness. Moreover, it opens up possibilities for

accountable and collaborative improvisation. Current systems often fail to integrate real-time capability and asset tracking, and bureaucratic demands slow down fast and flexible utilization of available resources and capabilities (The White House 2006). Using the methods outlined in Example 1, the emergency staff here confidently rely on the technologies. This enables publicly visible collaborative improvisation: Peter and Amrik can see where Jens is (and trust that this is live information) and work with Paul, Jens and eventually a patrol car crew to address the situation. It is easy to imagine how an expanded assembly – with more cameras, and tracking devices for every officer and patrol car, as well as mobile (simplified) Topos™ displays of *Overview* carried by every officer – could expand the capacity for such improvisation. It would be accountable in two senses: First, capabilities and resources would 'account' for where they are as they move. Second, it is possible to record and replay movements. While this may create dilemmas for professional accountability if analyses with hindsight are used to critique in situ decision making, such records – if used responsibly – could be an invaluable learning resource. Indeed, some recordings made during TSR were used for debriefing sessions after the event.

Example 3

This example shows that there are multiple layers and multiple practices of inspection: The fire service patrol officers drop into the command centre to pick up a new charged phone. They ask one of the developers (Jesper) if they could see the pictures they took on their last round (Figure 6.1). He opens the last picture displayed in Topos™. It shows the window sill of the command centre (where the developers charge the phones) (6.2)! This is unexpected. Reading the picture's full file name, which includes the phone's name (N95_3) and a time stamp (6.4), Jesper sees that it was taken just before the officers set off. He inspects whether a heartbeat is received from the phone and what happened to the 'missing' picture(s), utilizing a range of PalCom supported means for tracing communication among devices and services (Andersen 2007), which allows them to reconstruct the pictures' journeys.

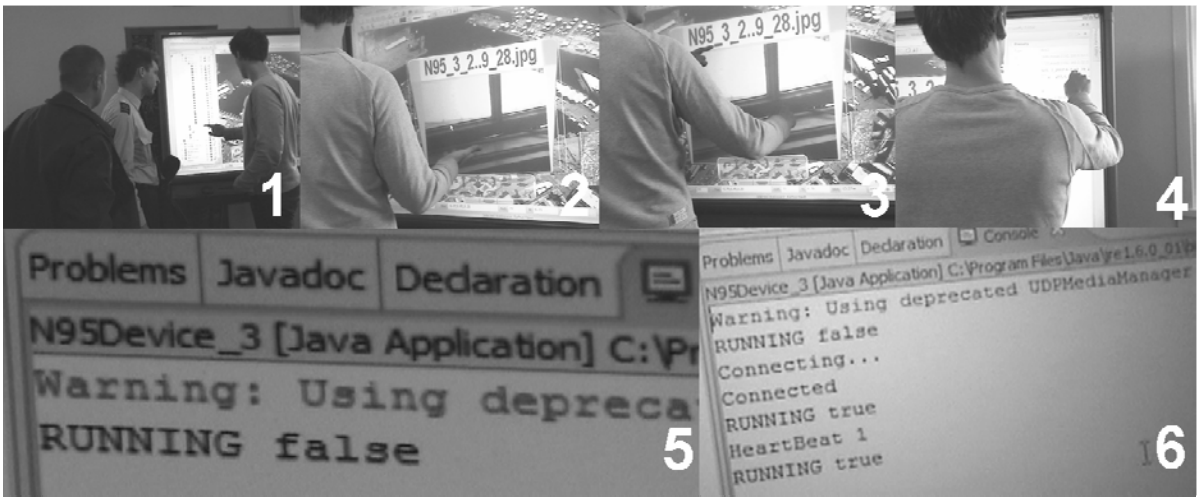

Figure 6: Making sure N95-3 is connected properly into the assembly.

They find that the pictures the patrol officers describe taking after setting off had been taken, tagged with their position, sent and saved at the command centre, just not sent to and displayed in Topos™. Restarting the gateway service to re-establish lost connections makes the missing pictures appear in their correct positions.

Lessons learned

Most of the work in this example was done by developers using low level interfaces and tools. The PalCom open architecture provides the possibility to inspect traffic along incoming and outgoing connections and the live 'primitives' produced, received and passed on by each assembled device and service (e.g. GPS coordinate strings, data packets) (Figure 7). Such facilities for *inspection of states, processes and connection* greatly enhanced the developers' ability to build trust in the technologies.

But inspecting not only helped the developers to pinpoint points of failure and fix parts of the assembly. It also helped them to explain to the professionals what was going on and demonstrate that they were in control – enabling one of the methods of establishing trust on the professionals' part: knowing that technicians are (justifiedly)

confident that things are working (or know why they aren't). There are thus multiple *layers of inspection* and *multiple practices of inspecting.*

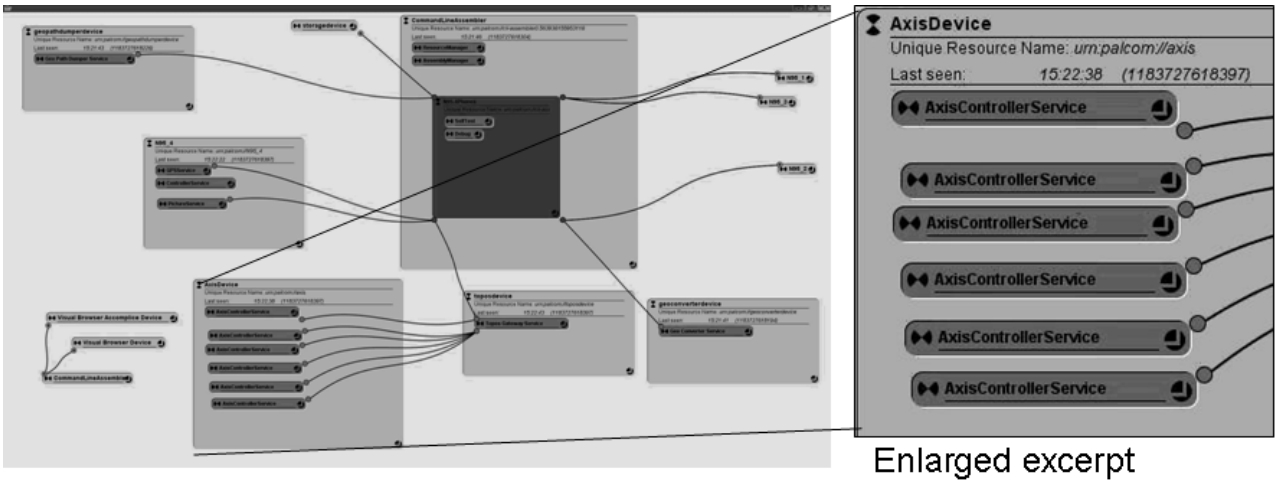

Figure 7: Screenshot of a PalCom Visual Browser showing active/inactive devices, services and connections in *Overview* with details of some devices and services unfolded (right) (Andersen 2007)

While the PalCom architecture in its current state makes crucial fundamental mechanisms for inspection available, it is obvious that more thoroughgoing awareness of, and trust in pervasive computing technologies assemblies could be further supported. This make us turn to a discussion of design implications.

DESIGN IMPLICATIONS FOR PERVASIVE COMPUTING FOR EMERGENCY VIRTUAL TEAMS

Pervasive Computing technologies could extremely productively support the work of emergency virtual teams. However, a professional leap of faith is made difficult by a design philosophy that seeks to hide the inner workings of the technologies involved. In this paper we have presented examples and reflections from experimental deployment of a prototype assembly of existing and prototypical pervasive computing technologies (*Overview*), built upon the PalCom open architecture (Andersen 2007), during the Tall Ships' Races in Aarhus 2007. These technologies embody a different design philosophy, one that explicitly seeks to enable people to 'look under the hood' of pervasive computing. One of the main drivers for this shift in design philosophy is the recognition that people need to be able to trust their technologies.

Through three examples of how *Overview* and the PalCom open architecture were used as part of the event management during TSR, we have demonstrated that trust is not a state of mind, or once-and-for-all accepted dependability, but practically, and often collaboratively achieved. We show how users build up trust in *Overview*, identifying a set of methods that can be actively supported through design. Drawing on our TSR experience, we can sketch out key implications for pervasive computing design for emergency virtual teamwork.

First, our attention must turn towards the process of innovation. Developing, and developing trust in, new technologies – generally – is inextricably entangled with developing, and developing trust in, new ways of working. Design should seek synergy with everyday innovation, because in order to anticipate and design for future practices, designers need the critical insight from professionals and from non-discursive embodied and tacit innovation. This can be achieved through experimental deployment of prototypes as part of as-realistic-as-possible real world work. In emergency virtual teamwork, such a participatory approach to innovation can help facilitate the realization of technological potential by balancing technologically ambitious design with 'graceful augmentation' (Jul 2007) and safe levels of redundancy.

Second, our experience with *Overview* and the PalCom open architecture suggests a range of design challenges for a fundamental re-orientation towards actively supporting methods of building trust in the design of pervasive computing technologies for emergency teamwork, including support for:

- *flexible redundancy* with regard to the methods of working up trust
- *flexible interaction* modes to suit multiple motivations and forms of inspection

- *quick and implicit experimentation* which allows quick probing of cause-effect relations in complex, distributed systems
- *inspection of states, processes and connections* to make it possible to examine what is going on, all the way down to the 'primitives' of computational processes, such as GPS strings or data being sent or received
- *multiple layers and practices of inspection* to enable different users to understand and trust technologies.

Our examples show that there were many different users during TSR with many different motivations, competencies and practices for working up trust and inspection (the different emergency responders, basic end-users, super-users and researchers/technical systems-supporters). Our final challenge is perhaps the most difficult: how to enable different users to translate complex live system information about computational operations into information they can understand. This clearly is not a matter just for 'once and for all' interface design, but a matter of (1) inventing new forms of collaboration between technical experts and end-users, (2) creating new professional roles and positions for technology management and (3) designing support for the assembly of relevant and appropriate accounts of technological states, processes and connections.

Third, the way in which the experimental deployment of *Overview* and the PalCom open architecture 'forced' a future in which professionals could begin to utilize pervasive computing technologies for real world work, provides insight into emergent future virtual emergency teamwork practices. It becomes clear that situation awareness (like trust) is not a purely cognitive state, produced by individual minds processing information, but a practically, collaboratively produced dynamic and at least partially public understanding. Through combining *multiple sources of situation evidence* the professionals begin to develop practices of *distributed collaboration* (e.g. in determining the troublesome-ness of a wrongly parked car, or the level of chaos caused by a queue) and enable *accountable, collaborative improvisation* (such as brokering meetings between colleagues who are in close proximity but cannot see each other, or sending resources to colleagues whose location is known without the need for description).

Clearly, our own design efforts are beginning to address these challenges, but leave much room for improvement – for example, rolling out (simplified) Topos™ displays of *Overview* to personnel on the ground, in vehicles, and remote locations (such as hospitals). Having had the possibility to implement *Overview* and the PalCom open architecture in real use settings, where real end-users – the emergency responders – used it for several days has given us invaluable input to our research and design. We hope that the challenges and opportunities we have identified can contribute to the further unlocking of the potential of pervasive computing technologies for emergency virtual teamwork.

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