Why Expressiveness Matters in Command & Control Visualizations

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Abstract. Crisis command centres often gather data from disparate locations and collect it for visualization on a large, shared screen. However, the resulting visualization often lacks expressiveness: it fails to express nuanced mediating characteristics about the information, such as specificity, urgency, awareness, or reliability. We suggest that our previous work on creating expressive realtime embodiments can inform the design of crisis management embodiments on large displays, improving communication and decision-making. We make several recommendations for future research directions.

Introduction

Crisis command-centres are increasingly using shared, surface-based displays for large-scale overviews of information (as described [1] and exemplified in [2]) and mobile devices are beginning to be used as the sources for information visualized on such displays. However, this important information often lacks expressiveness in its presentation: subtleties and nuances are not well expressed in state-of-the-art visualizations.

Consider, for example, a fire crew fighting a wild grass fire, such as the 2009 Oklahoma fires described in Vieweg et al. [3]. A crew chief has a mobile tablet

updated with information from the Command and Control (C2) centre. As the crew chief communicates with the C2 centre, either explicitly or implicitly through updates from the tablet, the information generated through this communication is displayed on a large, shared display in the C2 centre. To be effective and useful, this information should be mediated by its importance, urgency, reliability, accuracy, specificity, and the situational awareness of the chief. Such nuances will change how the information is visualized in the C2 centre.

Embodiments -- representations of remote collaborators, often designed to represent their physical movements in a workspace -- could encode much of the complexity that crisis management systems need to represent, including different kinds of uncertainty, emphasis, specificity, and temporality. As yet, embodiment designs do not support such subtleties of information visualization. Indeed, little is currently understood about how to present these information characteristics, despite their importance in communication, particularly where understanding is constrained by time pressure, such as in crisis management scenarios.

Previously, we have explored the idea of expressiveness in collaborative embodiments -- a way of describing the amount of information contained in distributed representations of users. We extend this idea to representing information in crisis-management collaborations, where the amount of information and the way it is presented can have a critical impact on the success of management. We believe that a more nuanced understanding of how embodiments are interpreted can resolve much of the more challenging aspects of information representation in geocollaboration and distributed crisis management.

For example, our recent work has shown that representing the height of deictic gestures helps distributed collaborators convey variations of confidence, specificity, and emphasis [4], concepts that are usually difficult to associate with geospatial data. We have also shown that adding temporal traces to data representations helps with awareness, increases the emphasis associated with the data, and provides additional tools for users in real- time communication [4-6]. Finally, because work in crisis management must move between local and distributed collaborations, we are interested in leveraging the work on social traces to support an awareness of the actions of distributed collaborators while a user's attention is elsewhere [7-8].

Our studies have raised questions related to how people, and their nuanced communications, might be better represented during distributed collaboration. We have begun to explore the design space of embodiments in the context of *fidelity* and *enhancement*. *Fidelity* is the faithfulness with which remote reproductions of

people and their actions are represented in a shared workspace. *Enhancement* is the augmentation of visual representations using data not available through the highest-possible fidelity. For example, enhancements may include: information about collaborators; their actions, status, and roles in the domain; the reliability of their information; and their situation awareness (so we can see what they can see). Both fidelity and enhancement are mediated by the level of augmentation (how much subtle information is emphasized), type of aesthetic (the artistic component of embodiment design which can influence perception and tap encultured responses), and the applied interpretation (information about the intuited intent of collaborators, such as the intensity of interest gathered from tracking eye gaze and other engagement metrics), all of which can have a profound impact on how visualizations are interpreted.

A key aspect of our investigation is the amount of information that can reasonably be used in these contexts. Crisis management is a time-constrained task, thus all information competes with other information. Therefore, any embodiment information added to an already complex C2 display will compete for users' attention, and may create information overload. Thus, methods of minimizing distraction and overload must be a priority when designing new information visualizations. We are beginning to explore the limits of what can be expressed and understood in this context, informed by earlier work on embodiments that shows that this limit is remarkably high [9].

Expressiveness in Distributed Communication

When groups of people work perform command and control activities on remote locations using large displays, a wide variety of information about the remote location needs to be displayed for effective collaboration [1]. This information includes practical information about who is where and doing what in the remote location, but also includes expressive information about the remote location and agents, such as workload, predicted performance, and awareness. As earlier, this additional information is not without cost, both in terms of production (the sender of the message) and in terms of consumption (the receiver of the message). A core challenge is to find mechanisms that allow people to be expressive through their embodiments to emphasize "important" aspects while de-emphasizing less important aspects (to reduce superfluous information for the receiver).

We have explored some of these ideas in a preliminary form for video-based embodiments of people's arms over distributed tabletops. In prior work [5], we applied simple non-photorealistic rendering techniques for video captures of people's arms as they gestured over a shared workspace. These filtration techniques were used to emphasize edges/boundaries of the gesture, or helped to

accentuate motion of a contact point on a tabletop surface. Importantly, they are not simply video reproductions of gestures - instead, specific *aspects* of the gestures are emphasized in a non-realistic way.

We see new opportunities for creating expressive visualizations through variations in the fidelity with which information is reproduced on shared displays and the enhancements that are applied to that information. Next we discuss how our ideas about expressiveness can apply to crisis management scenarios.

How Embodiments can be Expressive in Crisis Management

Embodiments already exist in most crisis management software packages as status visualizations. For example, a fire-fighting visualization might include a representation (either textual or iconic) of a crew of five people with two trucks and their fire suppression capabilities. This is valuable information, but fails to provide any nuance. For instance, embodiments should provide information about urgency, accuracy, probability, and awareness associated with the team's information. Perhaps the crew has been in the field for 14 hours and are in urgent need of replacement; is experiencing limited accuracy in their GPS reporting due to a mountainous landscape; are not yet aware of an updated weather forecast; and there is a possibility that the number of volunteers associated with the crew is wrong in the C2's records. We believe that embodiments in the C2 visualizations should provide clues about this information at a glance. In the following sections we introduce two ideas about how this can be done and one possible barrier to expressive embodiments.

Real-time Representations

There are many ways in which expressive embodiments can represent information in realtime for crisis management visualizations. Based on the previous example, we explore the representation of urgency, accuracy, and probability.

Representing urgency and emphasis
In our research on embodiments for distributed collaboration, we found that the height of gestures above a surface is key for indicating emphasis. Using features of enhancement, such as adding shapes, varying sizes, or changing colours can provide non-specific cues to the urgency or emphasis of embodiment information. In particular, repeatedly varying size, such as an expanding and contracting circle, is a clear indication of emphasis or urgency.

Representing specificity and accuracy
We have had success in visually representing specificity, and accuracy through the use of diffusion and shadows. The more sharp (less blurry or diffuse) an embodiment the more the information is interpreted as specific; the more diffuse, the less the information is interpreted as specific or accurate.

Representing probability and uncertainty
Uncertainty and probability are difficult to represent visually without undermining the readability of the primary information, although there has been extensive research on this topic. We have had some success in using a variety of temporal traces, visualized as fading or faded versions of the original embodiment to represent the possible historical or future movement of embodiments in two dimensions. More challenging, however, is indicating non-geographic uncertainty. In this context, we have begun exploring changing the fidelity of the underlying visualization, where possible mediating this change through the use of alternative aesthetics. This can be achieved through the use of alternative fonts, where data is in a written format, or different artwork where data is represented through images.

Each of these techniques for increasing expressiveness require further research, particularly in the context of crisis management, where the nuances in information representations can have a more significant impact than in many other domains.

Awareness of Past Events

In many situations collaborators may need to shift their focus or attend to details away from the collaborative system. In these situations waiting for an answer or entering into direct communication require more time than is required. Because timely access to nuanced information should be a central requirement, support should be built into systems to allow questions about past information to be answered. These can and should be supported without the need for direct communication with individual collaborators.

Gutwin and Greenberg described support for awareness as providing an up-to-the moment knowledge about others actions [7]. Tam and Greenberg focused on aspects of awareness that encompass asynchronous changes. They define *change awareness* as the ability of people to track asynchronous changes made by collaborators at different times [8]. In particular, Tam and Greenburg highlight that providing visuals of all history may be overly complex, because changes can occur in many different places, can be overlapping, and can be involve many different individuals or groups. To alleviate this potential complexity a viewer may want to query an interface interactively, to receive history only related to an object of interest. They defined three views of change in which a viewer might be interested:

1. an artifact-based view - relating to the physical objects required to support the work
2. a person-based view - relating to the people or groups who are in the collaboration
3. a workspace based view - relating to the geographical region where the work is taking place

This allows questions about who, when, what, where, and how relating to the object of the view to be addressed. For example, C2 might be interested in knowing details about a team, and engage a person-based (or team-based) view. In this view they may be able to answer questions related to *where* the team has been, *when* they arrived at their current location, *what* is their current location, and *what* was the urgency of their last request. Being able to answer such questions in a timely fashion may allow C2 to most efficiently make sense of a particular situation.

How Much is Too Much?

Common sense suggests that there is a limit to the amount of expressive information we can, and should, show in a single embodiment. Stach et al. found that people can track over 20 pieces of information encoded in telepointer- style embodiments, although they suspected that people were paying attention to only a subset of these when actually using their software [9]. This area remains largely unexplored, but it may be that the limit is on what expressiveness can be designed into embodiments without overly distorting the core information. Perhaps methods of de-emphasizing information will become particularly important in this context. We suggest that this is a key area for future research into expressiveness in embodiments.

Workshop Goals

Our expertise resides in understanding communication and designing systems that are responsive to a wide variety of expressiveness in communication. We have limited experience in the particular domain of crisis informatics but feel that our work can be applied well within this field and are seeking collaborative opportunities to this end. This workshop provides an excellent starting point for us in both extending our understanding of crisis informatics beyond the corpus of literature and in making connections for future research. We also believe that our approach to information visualization, an approach that seeks to embed subtle information in more standard representations, has much to offer in the context of crisis management.

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