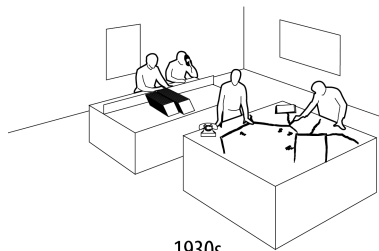
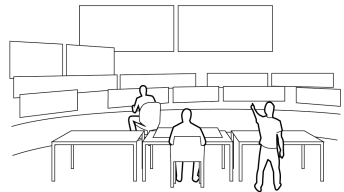
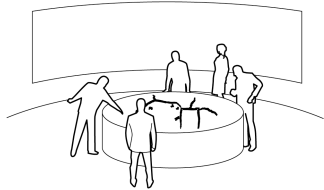

Tangible Tabletops for Emergency Response: An Exploratory Study



1930s



1990s



2000s

Figure 1. Collaboration in control rooms has changed over the decades, starting with early plotting rooms featuring physical models (top). During the 1990s, control rooms were equipped with vertical and spatially distributed screens (center). Now control rooms make use of larger vertical displays together with horizontal surfaces (bottom).

Andreas Kunz
ICVR, ETH Zurich

Ali Alavi
t2i interaction lab, Chalmers
ICVR, ETH Zurich

Jonas Landgren
Dept. of Applied IT, Chalmers

Asim Evren Yantaç
Yildiz Technical University, Istanbul
t2i interaction lab, Chalmers

Paweł Woźniak
t2i interaction lab, Chalmers

Zoltán Sárosi
INSPIRE, ICVR, Zurich

Morten Fjeld
INSPIRE, ICVR, Zurich
t2i interaction lab, Chalmers

Abstract

Effective handling of location-based data is important to emergency response management (ERM). Expert team members co-located around maps typically discuss events while drawing freeform areas or while using physical placeholders representing incidents. Key ERM functions are filtering data, selecting information recipients, searching datasets, drawing time-dependent freeform areas, and zooming in on one region while leaving others unchanged. Under time pressure the mouse and keyboard could be insufficient; intuitive graspable solutions, such as tangible user interfaces (TUIs), may be better suited for ERM. We present CoTracker, a tangible tabletop system with expected potential for ERM teamwork. On an interactive map expert team members can discuss an operational picture using TUIs like bricks, frames, and pens. With the participation of domain experts for cognitive walk-through studies, we examined how generic and specialized TUIs can support ERM-related functions. We present some insights into the design of ERM-focused tangible tabletops.

Author Keywords

Multiple TUI ERM, tabletop, tangible

ACM Classification Keywords

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Introduction

Emergency response has always been both a challenging case and an experimental base for emerging technology. In the early 20th century, strategy and emergency response took place around draft tables (Fig. 1, top). Experts worked around these draft tables with strategic information artifacts; their goal was to maintain control in dynamic and critical situations. Later on, computer-supported collaborative work focused on enabling information representation with distributed displays (Fig. 1, center). Today, twenty years later, experts visualize and discuss critical crisis scenarios on collaborative horizontal or vertical surfaces (Fig. 1, bottom).

While novel solutions in data visualization and display technologies provide sophisticated ways to represent continuous data streams, interaction techniques are being developed to manipulate the data. One efficient style of interaction is combining tangible user interfaces (TUIs) with tabletops [14]. This is beneficial because such situations require intuitive and direct manipulation of sophisticated information layers. We decided to tailor our in-house designed tabletop system, CoTracker, to meet the needs of ERM and then to test it. We examined the effects of using generic TUIs versus specialized TUIs. We combined TUIs with Graphical User Interface (GUI) elements to create ERM-related functions.

In this paper we first explore related work in this field, including previous work on cognitive support of TUIs [4,20]. Then, we present our system in terms of application software design. This is followed by a presentation of a proof-of-concept study. Based on our preliminary evaluation, we discuss how TUIs may

benefit ERM-related functions. We then suggest a re-design of the system that incorporates the findings of the study. The main contributions of this work are: (1) a proof-of-concept study of a tangible tabletop system for emergency management, (2) new insights into domain-specific use of tangible tabletops, and (3) a verification of past results concerning the combination of touch and tangibles in ERM work.

Related Work

Here we explore both the design space of tangible tabletops for ERM and how to construct TUIs for use on horizontal surfaces.

Tangible Tabletops for ERM

Emergency response teams provide a variety of expertise in situations where simultaneous multi-user interaction is required to make sense of critical and dynamic information flow and to coordinate decision-making. In a crisis situation, experts must make the most of their knowledge and experience and assess the information at hand most effectively. Research has been done on how to access and distribute key information in an ERM situation [7]. Rauschert et al. [17] examined how speech and gesture recognition can be coupled with a knowledge-based dialogue management system for storing and retrieving geospatial data. They showed how a multimodal, multi-user Geographical Information System (GIS) interface benefits collaborative work on large displays. Wigdor et al. [21] pointed out the importance of hosting experts in a shared horizontal workspace and allowing them to work on their particular subtasks without interfering with each other. Another possibility is the CERMIT system [15], where light-emitting tangible devices and mobile phones were used to interact with the tabletop

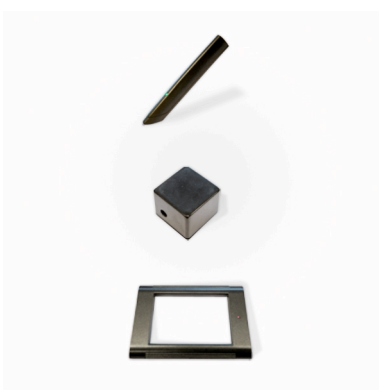


Figure 2. Tangible tools examined here (top to bottom): pen, block, and frame

environment. CoTracker aims at using distinct tangible artifacts for alternative functions; an early version was presented together with a tracking concept [1,2]. This was followed by uEmergency [16], a tabletop system developed for ERM that utilized both tangibles and multitouch. In CoTracker, we focus on the exploration and evaluation of tangibles in an ERM setting with an aim of supporting different levels of communication.

As a standard for integrated ERM simulation, a set of major data elements was suggested: areas, building-structures, chronology, demographics, and hazard-effects [10]. Typical applications in ERM are navigating through the map (e.g. specific zoom in a certain region while the rest of the map remains unchanged), filtering data (e.g. only information from a certain field unit), searching specific information (e.g. gas/oil pipelines, communication lines, etc.), and assigning tasks (e.g. only to fire-fighters). Users involved in time-critical planning of data with maps sometimes use physical tools like rulers, dials, and pens to share knowledge and to collaborate in creating a common operational picture (as shown by Ley *et al.* in [12]). However, the complex tasks of ERM cannot be handled using existing passive TUIs. These tasks require not only a simultaneous multi-device positional input but also the capacity for designated devices to precisely stream large quantities of information [1,2].

TUIs for Horizontal Surfaces

A potential exists for using tools different than conventional mice and keyboards for working on interactive surfaces under time pressure. User control of interactive surfaces can take different forms, such as touch-based, device-based, or in-air gestural input. Studies by Tuddenham *et al.* [19] hint that for some

time- and precision-critical uses, touch might not be sufficient. Here, we focus on device-based alternatives, such as graspable TUIs, sometimes called phicons [13]. TUIs are easily identifiable by their shape and are thus suitable for collaborative work around interactive tables. From our previous experience, we have learned that a majority of users expect TUIs to be more than simple point and click devices [15]. To meet this expectation, some researchers have tried to augment and ease the interaction between the user and tangible surfaces by employing malleable sand [9], clay [9], paper [18], or even magnetism [10] augmented by computer projections. These malleable or constructive objects from everyday life are easy to use due to their generic look and feel. In contrast, most TUIs have recognizable shapes, such as pen, brick, frame, palette, ruler, or caliper (Fig. 2). While we usually assign generic functions to these devices and use them in many different cases, we seldom create specialized case-specific devices such as a frame for multilayered data access or a palette for sketching. Ullmer and Ishii [20] proposed that specialized TUIs could offer richer interaction capabilities but at the cost of reduced flexibility. The degree of cognitive support offered by a TUI has been shown to be a function of the TUIs degree of specialization [4]. While malleable solutions have a lower degree of specialization, tools like frame, palette, ruler, and caliper are more specialized [19]. We believe that the inherently complex structure of an ERM case requires rather specialized TUIs. This is why CoTracker employs tailor-made tangibles

System Design

The design process

The design was informed by three primary perspectives; 1) The review of prior research in the

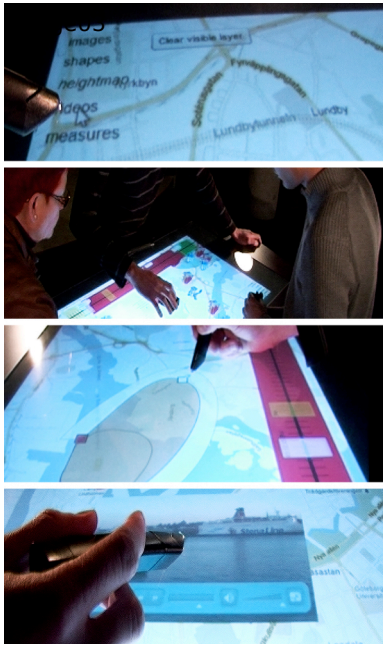


Figure 3 (top to bottom): The system offers interaction with five global layers (images, shapes, height map, videos, and measures); a specific layer is selected using the pen. Standard operations like placement of operational ERM units, such as a police car, a fire fighter, or a photographer, is activated using the “images” layer. The shape layer allows users to draw and modify time-dependent freeform areas. The video layer offers live streaming of video from an incident location.

field enabled us to extend our understanding of the requirements for interactive artifacts in an ERM environment. 2) Based on one of the authors’ (of this paper) extensive ethnographic research on IT use in the domain of crisis management, user needs and design considerations could be formulated and mapped to findings in previous field studies [3,11]. 3) In addition, an expert group was formed, consisting of crisis management specialists and fire fighters from the local municipality, to explore possibilities and insights related to the specific class of technological capabilities.

Furthermore, the exploratory nature of our work meant that we were to preliminarily evaluate ideas and eliminate potential culs-de-sac. Overall, we were guided by the need to provide the means for rapid coordination of multiple resources within a temporal dimension. We aimed to make the interaction intuitive enough to move the focus from the planning table to the actual units in the field and effectively utilizing the knowledge of the experts.

CoTracker enables following the course of actions in a crisis situation displayed on a map. The developments can be observed by manipulating the time axis. We anticipate that this functionality can be used both for reviewing past actions and assigning new resources based on predictions. Furthermore, users can outline areas on the map and place markers that indicate unit deployments or special events.

Our research has been guided by questions like the following: Is it better to have multiple tangible devices, each with a limited number of dedicated functions (that is: more space-multiplexing), or a limited number of devices where users of one device can choose among several functions (that is: more time-multiplexing)?

Should user interface designers employ generic or specialized tangible devices? What is a good balance between generic and specialized tangible devices? We also strive to investigate what the good balance between using touch and tangibles is in an ERM context.

Implementation

The hardware chosen for our exploration was much like the InfrActables [5] or the MightyTrace [6]. The application software we created is the contribution presented here. The system was designed to handle ERM scenarios; it supports brainstorming about past events and training, as well as supporting real-time emergency response. Past work on ERM settings shows that it is safe to assume that 3 to 5 experts working at command centers would typically use our system. The prototype we present makes use of a navigable map-based interface (Fig. 3) with different layers of information (freeform areas, geo-information, streamed field video, and distance information). Most functions require procedural use of interactive devices (Fig. 2) and layers. The *pen* offers generic GUI control functions, such as layer selection and timeline editing (Fig. 3). Depending on the layer selected, the pen also offers specialized functions, such as drawing of freeform areas, regular writing, and sketching. The *block* (or: brick) is used as a multi-purpose tool to pan the map when pushed and dragged and to zoom in/out when turned clockwise/counter-clockwise. It has the additional function of task assignment if a related layer is visible. The *frame* is a more specialized device used to access information layers located within the framed area. For example, layers of pollution data may be shown as varying color shades within the frame. This enables accessing additional information while not

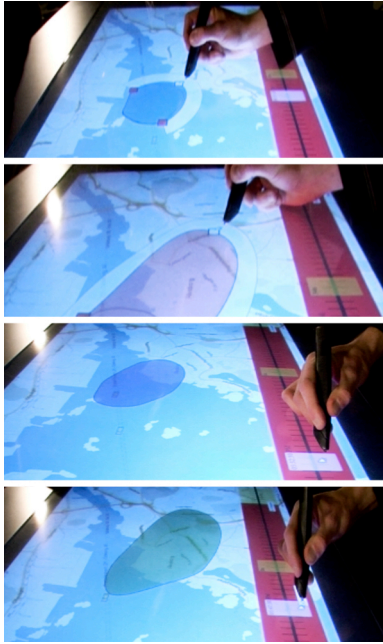


Figure 4 (top to bottom): Selecting a point and dragging it to modify a freeform shape is shown in the two topmost pictures. Modifying a shape using the time-line is shown in the two lower pictures.

modifying the overall map view (this makes it possible for single experts to perform micro-tasks without obtruding the work of the rest of the group). As an added feature, when pushed down onto the table's surface, the frame offers navigation and task assignment similar to that of the block.

To meet the needs of ERM collaboration we chose to develop a solution for time-dependent area editing. Indeed, crisis management experts often draw areas on paper maps, for instance to represent the spreading of a fire. Igarashi *et al.* [8] presented algorithms and applications where users could move and deform a two-dimensional area without manually establishing a freeform deformation domain beforehand. Inspired by this work, our current setup employs a so-called parametric curve controlled by pen and a GUI timeline (Fig. 4).

In order to prove the potential of CoTracker in a real setting and gain additional insights, we have conducted a proof-of-concept study in the form of a cognitive walkthrough.

Evaluation Method

We brought together 8 domain experts in 2 different cognitive walk-through sessions. Each session had a group consisting of 2 county crisis management professionals and 2 senior commanders from the fire brigade. The average age for the county crisis experts was 33 and 50 for the fire brigade members. Each group consisted of one female and three males. All experts were experienced with emergency and crisis management in regional crisis response centers. The study took place in a headquarters-like setting; each session lasted approximately one hour. Our study

started with a small survey asking for each participant's preliminary reflections on matching the functions with TUIs. Then, the conductor of the experiment briefly explained how the system worked, showing the functionalities of each tool and detailing the interface features. Subsequently, the experts were asked to handle a scenario which included the following tasks: (1) navigating a map, (2) outlining an incident area, (3) editing the affected area according to different time intervals, and (4) checking various overlaid information layers. Finally, the conductor of the experiment gave each expert a questionnaire about his or her experience with TUI functions.

Observations and Lessons Learned

The pen was an easy tool for the experts because they all have experience with Smartboard pens. Although the pen is a common tool for drawing and editing areas, using it as a pointer to select information layers or to manipulate the timeline required some learning. We observed that experts preferred to navigate using the block rather than the pen or the frame. While the participants stressed the need for precise navigation, the block failed to fulfill their expectations. The experts had difficulty performing the task assignment function with the block. Experts easily accessed additional information while leaving the rest of the map unchanged. While the frame also offered additional functions, such as navigating the map or assigning tasks, the experts made little use of these functions.

Generally speaking, participants reported having difficulties with the large number of devices. However, we observed that this was due to the need of performing several actions to achieve a given goal. Some actions require several steps of various TUI and



Figure 5 (top to bottom): We envision three new tool concepts where more precise device tracking and devices with a higher degree of specialization could benefit input. For the pen, streaming of its tilt-data and tip pressure value could provide new input modes. For the timeline function, a new handheld tool with two connected handles could support intuitive control of upper and lower values interval (concept and earlier example [4]). In an extended version of the frame, two adjustable knobs could enable bi-factorial browsing of map-based data.

GUI uses before reaching the intended action and can produce cognitive overload. Of course, one of the key principles in GUI design is to facilitate fast access to common functions, but the number of relevant tasks in ERM settings is significantly larger than in everyday use. That is why our participants reported a possible potential for a multitude of dedicated physical tools in our interviews. In line with the findings of Ullmer and Ishii [20], we found that experts favor well-designed specialized devices, but they made less use of them for generic functions.

From our evaluation we have learned that when employing alternative TUIs for ERM, we need to improve our understanding of how to connect TUIs with functions and data sets. Our studies indicated that distributed content strategy requiring procedural use caused usability issues. Thus, our initial research hypothesis that specialized TUIs would support ERM tasks is in principle correct. However, the tasks at hand in ERM require supporting much more complex working procedures by dedicated TUIs than it is known from other teamwork routines. Thus, the tools examined in this study (pen, block, and frame) could only partly fulfill these requirements, since they only supported less complex functions like drawing and pointing (for the pen), rearranging objects (for the block), and displaying additional information (for the frame).

While our evaluation gave many indications for re-design of our system, we consider two of them to be paramount: a need to combine touch-based input with tangibles and implementing artifacts with a higher degree of specialization (Fig. 5).

Discussion and Re-Design

The results of our proof-of-concept study yield several design considerations for future work with tangible tabletops for ERM. Firstly, our study replicates the results obtained by Qin *et al.* in [16] and confirms the need for combining multitouch and tangibles for effective work in crisis management. Secondly, we have determined an emerging need for specialized tangibles for manipulating data on a map for crisis management and confirmed the feasibility of that approach with domain experts. This realization and the recent developments in tabletop tracking technologies serve as an inspiration for a re-design of CoTracker.

Figure 5 shows three proposed tangible artifacts that are to further facilitate ERM work. We suggest enhancing the pen's functionality with tilt detection and re-implementing the now software-based timeline manipulation scale to a physical tool. Lastly, we propose augmenting the frame by adding knobs that can enable bi-factorial data browsing.

Summary and Outlook

We began with recognizing that collaborative use of large interactive surfaces benefits the ERM domain. There are several possible approaches: use of multitouch surfaces, employment of tangible objects like graspable devices, mechanic tools, clay-like materials, or combinations of these approaches. We examined generic and specialized TUIs based on our in-house CoTracker tabletop design. Throughout the study we observed that domain experts are used to working with the digital pen for taking notes, drawing freeform areas, and sketching. They are not used to using the pen as a pointer control tool. Moreover, the evaluation showed that a more precise tool than the block should

be used for navigation. We observed that the frame is an effective tool for ERM. This highlights the needs to include touch input and design more specialized TUIs for ERM work.

Future research will follow three goals. First, we aim to explore how a system equipped with multi-state TUIs may contribute to the practice of ERM. Second, we will study how to effectively pair TUI with touch-based GUI for ERM-related functions, such as time-dependent area editing, map navigation, and filtering of data sets. Third, our research will focus on developing a system with fewer generic devices but with a higher degree of specialization in devices that are already specialized. We will limit the number of devices to avoid complicating the system.

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