Emergency Response System on a Pen-Based Tabletop Display

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ABSTRACT
We conducted an experiment to investigate objective and subjective aspects of two pen-based interaction techniques, sketch and drag-and-drop, on a tabletop display. To provide a concrete testbed, we developed a simulated Incident Command System (ICS) that allows operators in a command center to populate a tabletop display map with critical incidents. We report here on some of the key empirical results and highlight the importance of understanding basic usability issues in new interaction techniques. We would like to discuss the implications of the empirical results and get feedback in the poster session.

Author Keywords
Incident Command System (ICS), tabletop display, pen-based interfaces, sketch, drag-and-drop.

ACM Classification Keywords
H5.2. User Interfaces: Input devices and strategies.

INTRODUCTION
There have been many approaches to designing a computer supported workspace for safety/time-critical decision support systems, including those using novel interaction techniques (e.g., sketch, voice, gesture, or multimodal-based) [2,4,7]. However, field professionals in such areas still seem to prefer a conventional 'pen and paper' workspace and are reluctant to adapt to computer systems, perhaps because current workspace designs do not fit the way they work [3]. This implies a need for a systematic investigation of usability issues in new interaction techniques. To this end, we implemented a computer simulated environment for an Incident Command System (ICS) on a pen-based large tabletop display. We investigated a variety of subjective and objective aspects of pen-based interaction techniques, specifically comparing sketch and drag-and-drop input methods.

Large-scale displays have shown to improve operator performance on spatial tasks [8], which is crucial in the context of an ICS. To provide such an environment, we built a custom tabletop [1] (Figure 1) that included four projectors with a combined display of 2560x2048 pixels. The display is projected onto a digitizer which uses a stylus as an input device. Projected displays were mechanically aligned so that they produced a single seamless display area. Pen-coordinates were translated to display-coordinates using a pre-computed 3x3 planar homography matrix [1].

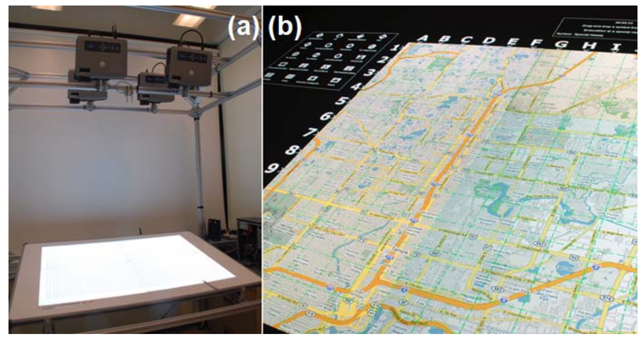

Figure 1. (a) tabletop structure (b) application on a tabletop

The layout of the application is shown in Figure 1b, including a 1600x1400 pixel map panel, a mission panel that announced incoming events, and two types of symbol menus: a *symbol legend* that listed all symbols in one panel and a *symbol tree* that categorized the symbols in a traditional hierarchical tree-structure style. The main task was to mark several emergency incidents on a map using a set of 20 symbols (Figure 2). Two existing input methods were developed in order to mark an incident: sketch and drag-and-drop (DnD). In sketch input mode, a symbol could be located by drawing it directly on the map. An existing sketch recognizer [7] was used to replace drawn symbols with symbol images. Symbol classification performance of the sketch recognizer was 97% in a 10-fold cross-validation test with 2760 samples drawn from 46 people (each person produced 3 samples for each of 20 symbols). In DnD input mode, incident symbols could be marked by dragging a symbol from a symbol menu to the map.

EXPERIMENT
Thirty-six right-handed participants ranging in age from 19-47 (*M*=25.4, *SD*=4.6), volunteered for this study, and were compensated with two free movie tickets. After participants completed a demographic survey indicating their prior experience with relevant technology, they were introduced to the tabletop system and had a practice session to familiarize them with sketch and DnD input.

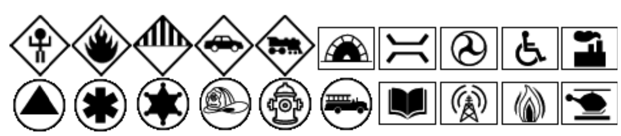

Figure 2. 20 symbols used in the application

The experiment used a partially-crossed mixed repeated-measures ANOVA design, with input mode and sketching complexity as within-subject variables, and frequency of use as a between-subject variable. The dependent variables included task completion time, location errors, and subjective preferences. *Input mode* compared different levels of recognition accuracy (75%, 90%) as well as different interaction techniques (sketch, DnD). The four factor-levels were (a) sketch input with 75% accuracy rate, (b) sketch input with 90% accuracy rate, (c) DnD input with symbol legend, and (d) DnD input with symbol tree. In order to precisely control the recognition rates, the test sessions used a simulated recognition engine. *Sketching complexity*, measured by drawing time, was considered to be an important factor since it can significantly affect objective performance as well as subjective attitudes. The 20 symbols were grouped into five symbol groups, to make up four factor-levels. *Frequency of use* was considered to be an important factor because those symbols that are used more frequently will be easier to remember, thus influencing objective performance and subjective attitude. It had three factor-levels, low (used once in a session), medium (3 times), and high (5 times).

RESULT, DISCUSSION, AND FUTURE WORK

The omnibus ANOVA revealed that all three factors had significant main effects on task completion time (input mode: $F_{3,104}$ =199.9, p<.001, sketching complexity: $F_{3,100}$ =11.6, p<.001, and frequency of use: $F_{2,296}$ =30.2, p<.001). Overall, the two DnD input methods were about two times faster (M=8.4s, SD=.2) than the two sketch input methods (M=15.2s, SD=.4). There was a significant interaction effect between input mode and sketching complexity ($F_{9,286}$ =5.6, p<.001) and a marginally significant effect between input mode and frequency of use ($F_{6,286}$=2.1, p=.058). As expected, the time delta between sketch and DnD increased as sketching complexity increased (Δ_1 =5.1s, Δ_2 =5.3s, Δ_3 =7.2s, Δ_4 =9.7s), and decreased as frequency of use increased (Δ_L=8.2s, Δ_M=6.2s, Δ_H=6.0s). One intriguing implication of these results is that for simple-to-draw, easy-to-remember symbols, sketch input can be competitive because operators do not have to scroll through an extensive menu. It is important to note that we used a small set of 20 for experimental control, but the actual set numbers approximately 200 [6], in which case task completion time in DnD would likely scale in a similar fashion.

A location error was logged when a participant placed a symbol at an incorrect location (i.e., the center coordinate of a symbol was placed outside of a 100x100 pixel target location). Participants using DnD made significantly more location errors (median=6.07%) than using sketch (median=3.57%) (p=.006). This is an important finding because maintaining high task accuracy is extremely crucial in the context of ICS. While it can be argued that the difference of few seconds in data entry time is not practically different, it can be strongly argued that errors in symbol location can be catastrophic in a time/safety-critical system because entire teams and resources could be inappropriately allocated to erroneous locations.

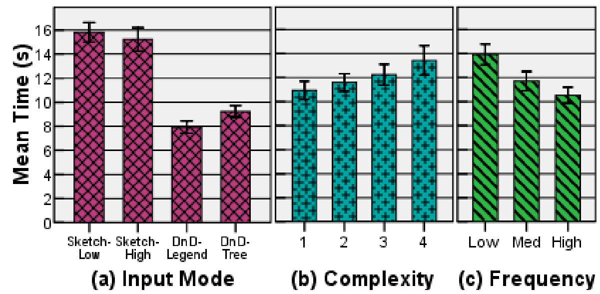

Figure 3. Task completion time (s) for (a) input mode, (b) complexity, and (c) frequency. Error bars indicate 95% CI.

Participants indicated their preferences by rating the four input methods at the end of the experiment. Overall, DnD input methods were significantly preferred over sketch input methods (p<.001). Many participants commented that it was tedious to repeatedly draw the same symbol, while repeatedly dragging the same symbol from a menu was not. However, the result could be different if the scenarios were more realistic (i.e., if more symbols from the set of 200 were needed). Some participants suggested that copy-and-paste of symbols within the map would be more time efficient to repeatedly generate the same symbols.

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