APPLICATION AND EVALUATION OF THREE ADVANCED C^4I DISPLAY TECHNOLOGIES

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SUMMARY

The digital Tactical Operations Center (TOC) is where the maneuvering, intelligence, logistics, air defense, artillery, and other digitized information must be brought into focus for the commander to view and understand. Electronic displays bring to the digital TOC programmable media, which can be updated as fast as the information flow dictates. However, current generation displays bring certain limitations to the TOC as well. They lack the size and the pixel density of traditional paper mapboards the commander and staff feel they need to manage the battle effectively. Under U.S. Army Federated Laboratory (1996-2001) funding, several methods of increasing pixel density were developed to provide near-term assistance to the display limitations in the TOC. These display technologies are the Hybrid Display (HD), the Actual Depth Display (ADD), and the Non-Linear Display (NLD).

The HD is a simple solution based on a “step back” in technology. A large display (plasma, projection, etc.) is combined with a clear acetate overlay map (reproduced from paper) to create a hybrid printed and electronic display. Fewer pixels are necessary to draw control lines and various unit and other symbols than to draw terrain. The symbols and control lines are the display's changing data. Software allows registration of the acetate map with respect to the electronic display; two known map coordinates are identified on the electronic display. This provides better accuracy than a paper map board and allows staff to change the acetate overlay quickly. The acetate does not interfere with interactive interfaces for the large screen (touch or pointing interfaces), so the display face can also act as an input device. HD integrates and exploits the advantages of printed and electronic media to overcome a problem that neither alone can manage. It adds dynamic symbol management to the printed map and display of higher resolution static information than the electronics are capable of displaying. Hybrids offer higher resolution displays now, and at the relatively low cost of current generation display technology.

Another way of overcoming display density limitations, as well as problems associated with display clutter and information fusion, is to stack information at different depths in visual space. One implementation uses two flat panel displays and an optical combiner glass to visualize both displays in the same visual space but at different distances from the viewer (Marshak, W. P., Razo, J., Marzen, V., and McKillip, R., 1997). Although capable of limited 3-D representation (only two depth planes), the depth separated display surfaces are more useful to declutter the information display; the user can focus on one depth plane, the other depth plane, or between depth planes to see both in focus. Although focus changes take longer than eye movements to make, they still permit a simple correlation of information between the surfaces. Information density in the display visual space is also increased, but not doubled. Our estimates indicate 1.4 times more information can be displayed on the overlapping surfaces. Format designers need to avoid certain configurations, like placing text on text (masking occurs) and large opaque fill areas on the near screen (occlusion).

Research showed that depth separations as small as 5mm viewed at 57 cm viewing distance were capable of allowing users to overcome the effects of clutter (Davis, Ntuen, Perry, and Marshak, 2000). Further, depth-separated displays were equal to side-by-side displays and superior to alternating pages of information on a single display while performing a monitoring task (Wesler, Lucas, Gallimore, and Marshak, 1999). Deep Video Imaging of New Zealand independently developed their own implementation of a depth-separated display and called it Actual Depth Display (ADD). Their engineers developed a sandwich of liquid crystal displays with a depth separation that is practical and only slightly larger than a single flat panel display.

The third approach to overcome display density limitations is the use of NLDs. Display format designers overlook the plasticity of the electronic display surface. Discrete displays (dials, tapes, paper maps) have uniform scaling and cannot change. Electronic displays have no such limitation. Displays, including maps, can be stretched or compressed in a non-linear manner, permitting zones of higher or lower resolution not unlike the way the human visual system varies receptor cell densities in foveal and peripheral vision. Mountjoy, Ntuen, Converse, and Marshak (2000) showed that users easily adapt to NLD; and the transformations, though sometimes taking longer to use, do not cause significant decrements in task performance.

A particularly useful non-linear transform is what we call the "modified fisheye" insert, which imbeds inside a medium scaled map a magnified lower scale center area, surrounded by a higher scale surrounding area. This is done so that the insert occludes none of the earth's surface. The modified fisheye permits a larger field of regard without sacrificing all detail, in a small overall footprint. It is particularly well suited for egocentric displays because compression is radial about its center of reference and only the distance and not the direction of objects from the center is distorted. NLDs can be applied to maps, photos, and graphics of any type. The NLD inserts require no user mental transformations between the insert and the remainder of the map.

An experiment was conducted to test the relative value of HD, ADD, and NLD technologies doing realistic C4I tasks. A collaboration of Army Research Laboratory (ARL), Battle Command Battle Laboratory – Ft. Leavenworth (BCBL-L) and SYTRONICS compared performance of officer participants from BCBL-L and Command and General Staff College using electronic displays and paper planning materials on two matched planning scenarios. The study was conducted inside the Mobile Integrated C^3 Environment (MIC^3E) devices, computerized mock-ups of an advanced concept display suite for planning on the move. MIC^3E was developed to demonstrate how a variety of display technologies could be implemented in the small confines of an interim force or Future Combat Systems C^4I vehicle. The scenarios required three stages: 1) terrain analysis, 2) signals intelligence analysis, and 3) a maneuver decision. The stages used interactive mapboard like software called TACTICS to test the HD doing terrain analysis (requires detailed map), ADD doing intelligence analysis (organizing and decluttering high density information), and NLD maneuver decisions (detail at specific locations).

Both objective and subjective measures were used to ascertain the effectiveness of the electronic displays compared to their corresponding paper planning. Objective measures include number and quality of avenues of approach identified, unit placement accuracy from intelligence information, and differences in replanning decisions. This analysis is in progress at submission time and will be presented in the poster. Subjective measures will compared the relative merits of the different electronic displays compared to their paper counterparts. Preliminary findings indicate that the officers were favorably disposed to the ADD and NLD displays, but did not like the HD display.

Observations made during the experiment indicate more research is needed to determine how best to design overlays for the HD. Officer planners indicated that use of color and slightly lower terrain density would have facilitated use of the HD in the experimental task. There was frequent praise for the ADD in the intelligence task; planners liked to easily separate the data in depth planes and to use temporal flashing and depth jumping to highlight information. There were also favorable comments about the NLD inserts, with officers indicating it was easier to extract detailed information about friendly and enemy unit dispositions. These results suggest at least ADD and NLD may improve information displays in command and control settings and provide display designers with information concerning how to implement these new display technologies into Future Combat Systems and Objective Force mobile and fixed command posts.

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