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Clearing up the clutter

Maura C Lohrenz, Michael E Trenchard and **Melissa R Beck** give a brief history of military cockpit displays, and highlight the research taking place to enhance future moving map capabilities…

Digital moving map displays have been used in military aircraft since the early 1990s, providing heightened situation awareness to pilots and navigators who previously relied on bulky paper charts for navigation. The original cockpit moving maps (first installed in the F/A-18 Hornet and AV-8B Harrier aircraft) displayed digitally scanned versions of standard paper aeronautical charts at scales ranging from 1:250,000 (Joint Operational Graphics – JOG) to 1:2,000,000 (Jet Navigation Charts – JNC). The charts were tiled into geospatial segments and digitally 'pasted' together to create seamless, raster, global coverage at the available scales. Pilots were familiar with these charts, so they adapted easily to using the digitally displayed versions.

However, there were problems with these original displays. Older charts adjacent to newer ones revealed widely varying cartographic symbology, colours, and even differences in geographic features (eg. roads or contour lines that simply ended at a chart boundary), as seen near the top of Fig. 1. Zooming in or out of the display resulted in a complete change of chart; for example, 'zooming in' on a 1:500,000 Tactical Pilotage Chart (TPC) would switch the display to a 1:250,000 JOG, rather than a zoomed in version of the TPC. Because different chart series used very different symbology, this abrupt change could result in a loss of situational awareness for the pilot, as

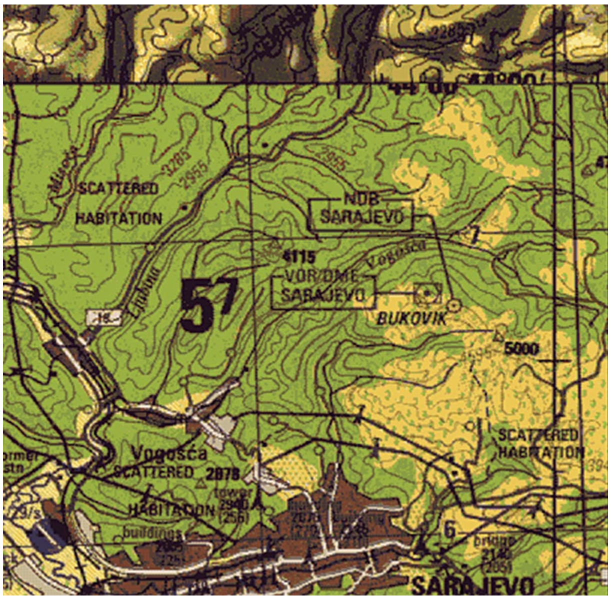

Fig. 1: two adjacent charts with very different cartography (evident at the boundary between them, near the top of this figure)

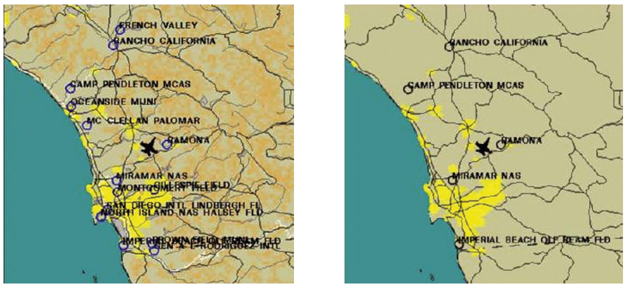

Fig. 2: TAMMAC supports the display and decluttering of vector overlays

cartographic features and landmarks were suddenly added or deleted from view. In addition, these raster charts were overlaid with mission planning symbols (routes, targets, etc.), which could make the displays quite cluttered and difficult to read. Since the underlying chart was simply a raster picture, it could not be 'decluttered' by removing or de-emphasising less important features. Therefore, the amount of new information that could be added to the display was limited by the negative impact of clutter.

In 1996, the US Naval Air Systems Command (NAVAIR) asked scientists at the Naval Research Laboratory (NRL) to help establish map data requirements for its next generation moving map display, known as the Tactical Aircraft Moving Map Capability (TAMMAC) system. TAMMAC was to replace the original digital moving map system in existing F/A-18 and AV-8B aircraft and would be installed in the new Super Hornet (F/A-18 E/F variants) and selected helicopters. A primary navy goal for this new system was to enhance situational awareness and aircrew mission effectiveness without further burdening pilot task workload. In other words, any new capabilities implemented in the moving map display should not be too labour intensive, since a pilot's mission was already very complex.

To ensure end-users' requirements were met, NRL investigators conducted one-on-one aircrew evaluations of a wide variety of map data types (both topographic and tactical) and map display parameters, including feature size, orientation, colour, symbology, etc., to help define an optimum map design for cockpit displays (Lohrenz et al, 1997). NRL designed a series of interactive demonstrations based on common digital moving map scenarios, using standard and prototype digital map products from the National Geospatial-Intelligence Agency (NGA), and presented the displays to experienced aircrew from diverse aircraft platforms. We asked the pilots to evaluate each moving map display in terms of its potential usefulness for their specific missions. Many of the recommendations from this study were implemented into TAMMAC, including the use of vector chart databases to support dynamic decluttering and geospatial data queries (Fig. 2), the ability to display terrain elevations with sun angle shading (Fig. 3), and the ability to display satellite imagery.

Current military cockpit displays

Today, TAMMAC supports the F/A-18 C/D/E/F Hornet variants, AV-8B Harrier, H-1 helicopter, and V-22 Osprey programs in the United States. F/A-18 programs in Finland and Switzerland also use TAMMAC, and aircraft in Canada and Australia are in the process of upgrading to TAMMAC.

TAMMAC efficiently assimilates and displays vast amounts of information including tactical situation, mission status, aircraft performance, weapons status, and sensor information within a geospatial reference. The principal benefits of TAMMAC include increased mission effectiveness and survivability arising from improved situational awareness, reduced crew workload, and enhanced capabilities for precision navigation, targeting, obstacle avoidance, and mission re-planning (CNO, 1996).

TAMMAC's baseline set of geospatial capabilities include standard NGA raster products, such as aeronautical charts (Compressed ARC Digitized Raster Graphics), terrain elevations (Digital Terrain Elevation Data, level I), and satellite imagery (Controlled Image Base, five and 10 metre resolutions). TAMMAC also supports several 'vector map' overlays, including vertical obstructions (a database of towers and other potential hazards to low flying aircraft), ESRI shapefiles, tactical warfighter symbology (MIL-STD-2525), airfield data (Digital Airfield Flight Information File), and military flight zones (Weapons Engagement Zone Overlays).

TAMMAC supports flight planning tasks by allowing the pilot to set and display multiple waypoints, multiple routes between waypoints, non-linear (serpentine) legs, latitude/longitude and MGRS grids, and threat overlays. TAMMAC also displays points and polylines derived from vector geospatial information and metadata. A vector settings file allows the pilot or navigator to define various attributes associated with the relevant vector features, including colour, font, display priority, and declutter level. For example, the user may establish a setting to restrict the display of airfields to a minimum runway length (obtained from metadata) for a given aircraft platform, thus eliminating the display of superfluous airfields not applicable to that particular airframe. Priority settings allow the user to establish which information is most critical and protect it from being overwritten or obscured by other overlays. Vector information may be decluttered based on the current display scale. For example, some information may be applicable at a scale of 1:250,000 but may be far too cluttered at a scale of 1:1,000,000. The vector settings file allows the user to establish minimum and maximum scale thresholds for display of vector geospatial information that TAMMAC supports (Harris, 2006).

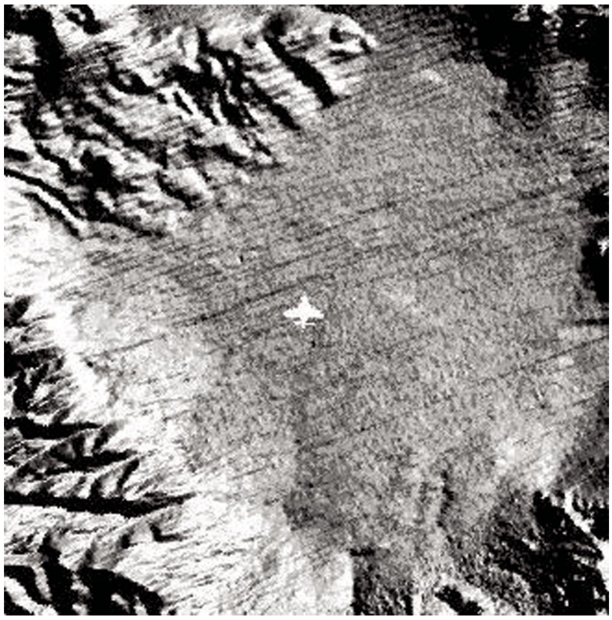

Fig. 3: TAMMAC supports digital terrain elevation data with sun angle shading in 2D

Future moving map capabilities: clutter research

Clutter remains a problem, however, for modern electronic chart displays ranging from complex, multi-function aircraft displays (including TAMMAC) to simple handheld GPS devices, as well as internet-based electronic chart displays that help people plan cross-country trips (eg. mapquest) or 'fly over' and view any place on the globe (eg. Google Earth). As new data sources become available, users are tempted to display everything of interest: digital charts, satellite imagery, terrain elevations, weather data, routes and other overlays. The ensuing clutter can impact a person's ability to access, interpret and effectively use the displayed information (Lohrenz, 2003).

NRL is investigating how to declutter electronic geospatial displays more 'intelligently': first by estimating display clutter as a function of how likely it is to impact a users' ability to locate some piece of information on the display, and then using that clutter estimate to determine how much information should be removed to improve search performance. We have developed a model of display clutter comprised of global and local components, which we have compared with both subjective clutter ratings and target search performance. Our results suggest strong correlations between our global clutter metric and subjective ratings, and between our local clutter metric and search performance (Lohrenz et al, in press).

We describe global clutter as the total amount of clutter in a display, and local clutter as the amount immediately surrounding some target of interest (eg. an airport or elevation symbol). We theorise a combination of global and local clutter impacts as visual search (finding the target of interest). In particular, we predict visual search is largely affected by local clutter: if the area surrounding a target is cluttered,

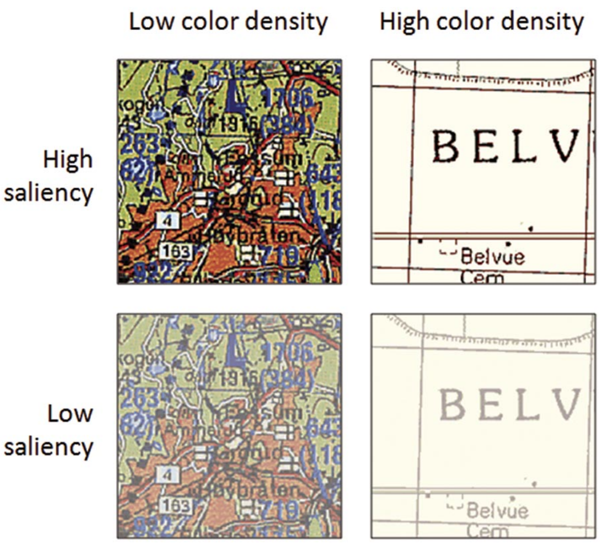

Fig. 4: the theorised impact of colour density and saliency on perceived clutter

the target will be harder to find. However, if people perceive the entire display as very cluttered (high global clutter), they may search more slowly and carefully than if they perceive it as uncluttered (low global clutter).

We suggest clutter is a function of 'colour density' and 'saliency' (Fig. 4). We define colour density as a measure of how tightly packed similar coloured pixels are within an image. We compute this by clustering all the image's pixels in 3D (2d location and colour), such that adjacent pixels of similar colours cluster together, and calculating the density of pixels in each cluster. Each cluster models a visually discernable 'feature' on the display. We compute saliency as a weighted average of colour differences among adjacent features (clusters). Greater colour differences result in higher saliency; highly salient features are typically easier to detect. Lower colour density suggests higher clutter, especially when saliency (between features) is also high. When saliency is low, colour density has less impact on clutter because features are less discernable.

In an attempt to correlate our clutter model with user performance, we asked 55 undergraduate students at the Louisiana State University to locate a particular symbol (the target) in 54 different aeronautical chart displays. The displays reflected varying levels of global and local clutter, as computed by our model. We measured the length of time each student needed to find the target in each chart, and whether he or she was correct. Later, we also asked the students to rate how cluttered each chart appeared, from 0 (no clutter) to nine (extremely cluttered).

Both global and local clutter slowed the students' search time, as expected, with the effect of local clutter increasing as global clutter increased. Interestingly, global clutter only affected the percent of correct trials when local clutter was high. Similarly, the effect of local clutter was largest when global clutter was also high. Finally, there was a strong correlation (r = .77) between local clutter and search time.

Only global clutter had an effect on subjective clutter ratings, as expected, since local clutter is target specific, and the students were not asked to rate how cluttered the target was (only how cluttered the chart was). There was a very strong correlation (r = .86) between our global clutter metric and mean clutter ratings.

Based on these results, NRL has been funded to continue researching clutter over the next three years, to develop an expert system capable of more 'intelligently' decluttering electronic chart displays. NAVAIR plans to integrate this expert system into future versions of TAMMAC.

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Maura C Lohrenz
Naval Research Laboratory

Michael E Trenchard
Naval Research Laboratory

Melissa R Beck
Louisiana State University

For further information please contact:

Maura C Lohrenz
Team Leader

Geospatial Processing and Analysis Team
Naval Research Laboratory
Code 7440.1
Stennis Space Center
MS 39529
USA

Tel: +1 228 688 4611

mlohrenz@nrlssc.navy.mil
http://mmc.nrlssc.navy.mil