Electronic Moving Map

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Introduction

The U.S. Navy has identified the need for an accurate, user-friendly navigation device to guide amphibious craft drivers. The standard navigation equipment in these craft has proven inadequate. Problems associated with the current navigation processes include, but are not limited to, low visibility, complex task management, and cramped internal space.

A moving map system provides the user with an accurate and visual depiction of the operating environment. This enhances both the driver's and the navigator's situational awareness, which is required for critical decision-making and operational safety. The Naval Research Laboratory (NRL) has been developing and testing moving-map devices hosted on commercial hardware and software in an effort to demonstrate such a navigation system on a variety of platforms. This system would provide helpful information to the craft operator, including determining position, displaying position, aiding in controlling position, and displaying waypoints.

Background

The Amphibious Assault Vehicle (AAV) (Figure 1) is equipped with few navigational aids, and the crew has limited visibility from inside the vehicle. The crew chief uses a periscope – or intermittently pops the hatch – for improved visibility. The driver has limited visibility through small windows, which are often obscured by sea spray, so the driver must rely heavily on the crew chief for direction. In some cases, the crew chief is issued a Precision Lightweight GPS Receiver (PLGR), which displays vehicle location as latitude and longitude coordinates on a small handheld device, but the PLGR is not available on all AAVs, and many crew chiefs (including several who participated in our demonstrations) are unfamiliar with its operation. Many crews do not even have a compass. Some AAVs may be equipped with a thermal imaging display in the future, but this has not been installed in any vehicles to date. The United States military has recognized the threat posed by mines on land and in the sea, and has taken many steps to address that threat. "Both historical precedent and the nature of today's asymmetric threats indicate that [the seas] will be mined, making mine countermeasures capabilities (MCM) a critical element of our operational requirements." (Johnson/Jones, 2000)

Figure 1 – AAVs on the Beach at Camp Pendleton

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Approach

The baseline mode of AAV operations chosen for this study called for the crew chief to use a hand-held PLGR and relay positional information to the driver, who then made course corrections. For our comparison case, the driver could view the moving-map display directly, and the PLGR was not used. Differential Global Positioning System (DGPS) positions and starting / ending timestamps were recorded by the NRL-MM system computer along the tracks traversed during demonstration runs. Informal interviews with crewmembers were conducted before and after each run to obtain crew feedback, address concerns and answer questions.

NRL Moving Map System

The NRL Moving Map navigation system integrates relatively low cost, commercial off-the-shelf (COTS) DGPS hardware with government off-the-shelf (GOTS) moving-map software. Table 1 lists system hardware and software components. The system includes a DGPS antenna and receiver capable of establishing exact position within 5-meter accuracy. DGPS data is processed by a high performance, ruggedized, water-resistant computer running the FalconView program, a component of the Portable Flight Planning System (PFPS) software suite. The system can be loaded with a full range of military standard format charts from the National Imagery and Mapping Agency (NIMA), the National Oceanic and Atmospheric Administration (NOAA), and various conversion chart imports (such as geo-rectified GEOTIFF formats) of other non-military standard commercial products. Overlays (e.g., lane geometry) can be used to enhance situational awareness. Figures 2 and 3 show an example of a complete lane and a zoomed-in view that the driver might use, respectively.

Table 1. Components of NRL Moving Map System

Hardware Components	**Software Components**
Argonaut computer	Windows 2000 Operating System
Furuno DGPS receiver (GP-36)	FalconView (PFPS)
Furuno DGPS antenna	**Heading Sensor Integration Software**
1 Nauticomp display - 10.4"	
Furuno Magnetic Heading Sensor (PG-1000)	

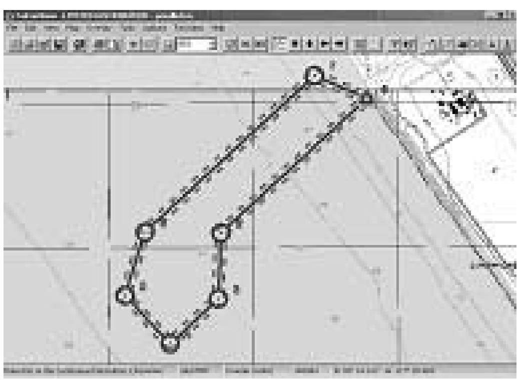


Figure 2 – Lane Geometry

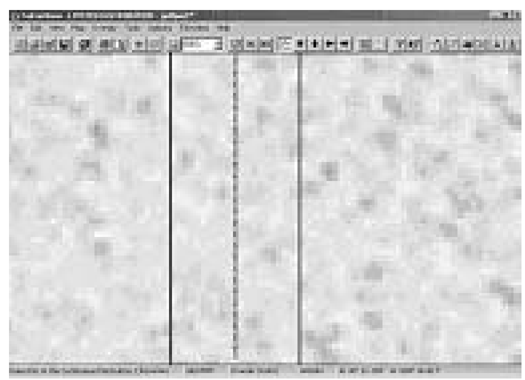


Figure 3 – Zoomed-In View

The computer, DGPS receiver, and heading sensor are all located in the aft of the vehicle. The computer is contained in a water-resistant case (figure 4), and secured to the starboard side troop bench. This configuration is for a prototype installation, as the system location is not currently reasonable for actual military operations. The display is attached to the driver hatch, with an adjustable mounting. The DGPS antenna is located just forward of center on the outside of the vehicle. Figure 5 shows all of the major hardware components. Figure 6 shows the driver's display, with the AAV driver hatch open. Figure 7 shows the display as it appears during actual operation.

Figure 4 – System Location

Figure 5 – Hardware Components

Figure 6 – Display (Open Hatch)

Figure 7 – Display (Closed Hatch)

<u>Demonstrations</u>

NRL has demonstrated the moving map system on AAVs several times in Camp Pendleton, CA, and Gulfport, MS. In addition to the AAV, NRL has also demonstrated this system on the Navy's Landing Craft Utility (LCU) and Landing Craft Air Cushion (LCAC). The main concern of this paper, however, is the AAV demonstrations.

The first AAV demonstration took place in May 2002, in Gulfport, MS, with the cooperation of the 3rd Platoon, Company A, 4th Assault Amphibian Battalion Reserve Unit. Preliminary data from these tests, collected by both NRL and the Coastal Systems Station (CSS), suggested that the moving map supports improved lane navigation performance, compared with the use of a PLGR. Crew feedback was also very positive: AAV crewmembers reported that the moving-map system was easy to operate with minimal training and very effective in helping operators keep the vehicle within the lane. As one operator put it, "This is a step in the right direction!" (Lohrenz, et al., 2003)

A following demonstration at Fleet Battle Experiment-Juliet, Camp Pendleton, CA (July 2002) elicited many insightful comments and suggestions for improvements. Several crewmembers mentioned that when the vehicle was stationary, the map display rotated, causing driver disorientation and annoyance. When the vehicle is stationary, the DGPS can not calculate heading, so it will emit random "guesses," frequently causing a radical change in the perceived orientation. After raising these concerns, NRL was funded by the Office of Naval Research (ONR) to integrate a magnetic heading sensor into the system, effectively stabilizing the map display.

The heading sensor integration was tested in Gulfport in October 2002, and again in Camp Pendleton in November 2002. These demonstrations proved the effectiveness of adding the heading sensor to the system. The drivers reported that they had a better awareness of the vehicle's orientation, without having to raise the hatch and visually locate their position relative to the beach.

Final tests and demonstrations of the moving map system took place on AAV platforms during the Transparent Hunter 2003 (TH03) exercise in January 2003 at Camp Pendleton.

<u>Preliminary Results</u>

Data was collected from each of the demonstrations, and results were calculated using cross-track error (CTE). CTE is calculated as the perpendicular distance between the planned route and the actual track (recorded as a series of latitude and longitude points obtained from the DGPS receiver):

$$\mathbf{CTE_P} = \mathrm{ABS}\,[(Y_E-Y_S)(X2M)(Y2M)(X_P-X_S) - (X_E-X_S)(X2M)(Y2M)(Y_P-Y_S)] \,/\, \mathrm{SQRT}\,[\,(X2M(X_E-X_S))^2 + (Y2M(Y_E-Y_S))^2]$$

Where (X_P,Y_P) = longitude (X) and latitude (Y) of the DGPS point along the actual track,
(X_S,Y_S) = longitude and latitude of the starting point of the planned route segment,
(X_E,Y_E) = longitude and latitude of the ending point of the planned route segment,
X2M = constant to convert longitude into meters (for the average latitude of the course),

Y2M = constant to convert latitude into meters (which is independent of longitude).

The CTE for the entire track is calculated as the average of the CTE_P's for all points recorded along the track. The track is broken into turns and straight sections, and average CTE values are calculated separately for each section, for comparison purposes. The minimum lane width required by a vehicle can be approximated in terms of the CTE: ($\mu_{CTE} + 2\sigma_{CTE}$) accounts for 95% of the variability of the track. Therefore, the tops of the error bars in figure 8 provide a reasonable estimate of the minimum required lane width for the AAV platforms used in this study (Lohrenz, et al., 2003).

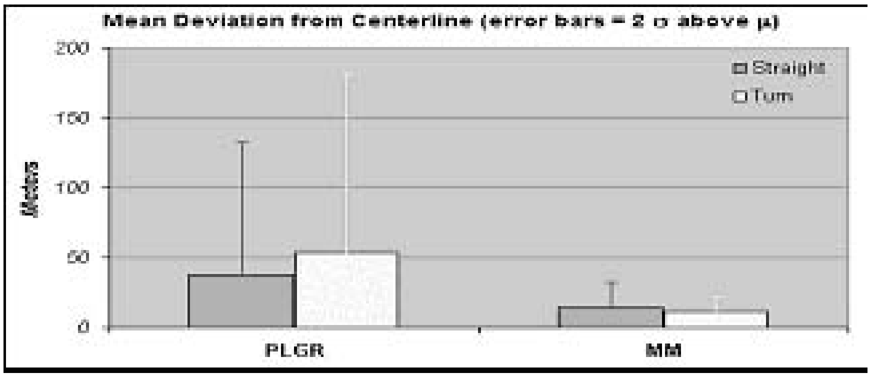
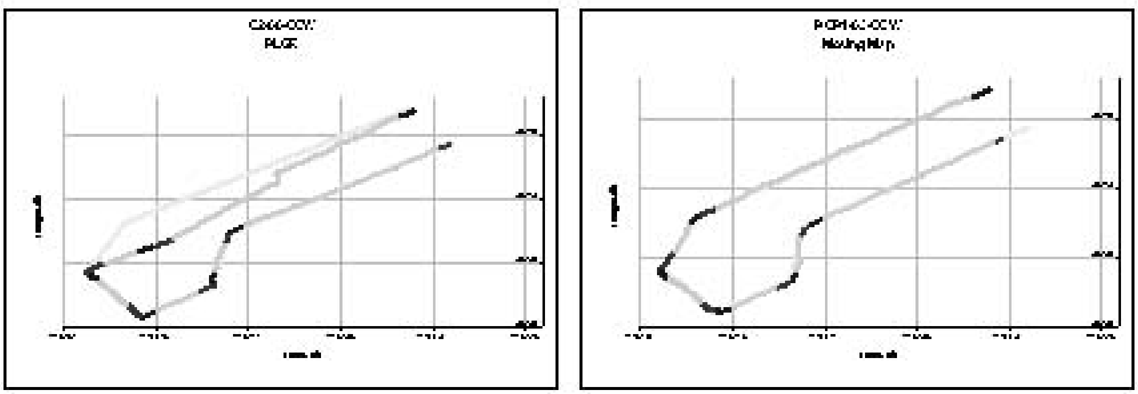


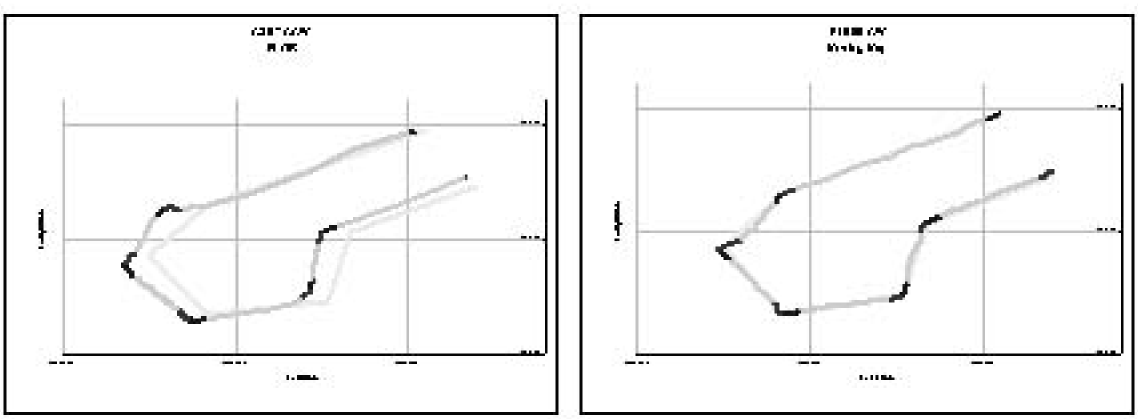
Figure 8 – Sample Data Results

Figures 9 through 11 show examples of different AAV runs from each demonstration location. The difference between navigating using the PLGR and using the moving map is clear.



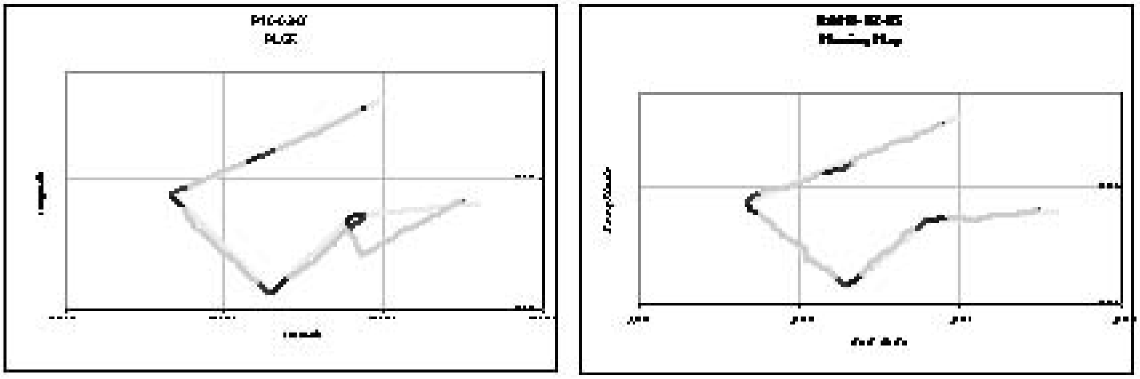
(a) PLGR (b) Moving Map

Figure 9 - July 2002



(a) PLGR (b) Moving Map

Figure 10 - November 2002



(a) PLGR (b) Moving Map

Figure 11 - January 2003

Conclusions

User feedback indicates that the drivers were extremely satisfied with the use of the moving map display. Based on preliminary findings, it was clear that without the moving map system, the driver's visibility was so limited that it was difficult to remain in a predetermined lane. This was the case even when the drivers were receiving direction vectors based on the military PLGR. When using the moving map display (which was physically located 6 inches away from the driver's face) the driver was able to remain very close to the center of the navigation lane. The navigation lanes were intentionally not set to be perpendicular to the beach but instead, oriented at an angle that would make it very difficult to use visual references to maintain accurate navigation. One promising comment noted, "This was the most accurate set of beach landings the drivers had done."

From the data accumulated to date, NRL has shown that it may be possible to reduce the width of cleared lanes through mined areas. However, it has also been suggested that the moving map system be used to navigate *around* known mines and/or mined areas. By using a moving map system in this fashion, it may be possible to completely eliminate the need to clear the mines at all, leaving only the need to locate them. This has the potential to save time, money, and possibly the lives of those involved.

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