THE EXPLOITATION OF DIGITAL DATA THROUGH ELECTRONIC DISPLAYS

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ABSTRACT

As recently as 1981 the majority of the production at the Defense Mapping Agency (DMA) was in the form of traditional paper products such as maps and charts. The emergence of sophisticated and miniaturized computers and computer processes is revolutionizing cartographic techniques at DMA such that over half of the Agency's products are now in digital form in support of computer based planning, charting, and weapons systems. DMA is in the process of building and loading a very large digital data base, with the potential to be exploited in more ways than currently defined Department of Defense applications. Objectives to be achieved are: increased productivity, standardization, quick response to user needs, cost savings, flexibility, and universal application. Optimal exploitation of the DMA digital data base, originally designed to support the output of feature data in a format suitable for lithographic reproduction, will require a reevaluation of the constraints and opportunities inherent in electronic display technology. This paper will address the potential for DMA to develop a digital data base that can indeed be exploited for universal applications on electronic displays.

BACKGROUND

A prime mission of a mapping and charting organization should be to present and to communicate its product to the user in the best way possible. In the past, and for many current products, lithographic printing was the "best way" to satisfy user requirements. The traditional format of the paper maps and charts produced by DMA reflect considerable effort by planners and cartographers to design stable products which still serve a multitude of users and uses. These products have integrated the requirements for feature selection, density, symbology, and scale for optimal portrayal of the contemporary conditions of the environment on a stable two-dimensional medium. The results of these efforts have been accurate depictions of all pertinent factors, easily interpreted by the user regardless of the purpose or use.

The need for mapping, charting, and geodetic (MC&G) products for computer-based planning, training, and weapons systems has forced DMA to change from an analog to a softcopy emphasis.

This transition from analog to digital mapmaking has progressed to where more than half of DMA's efforts are now directed towards the production of digital products, some being used directly by on-board computers of "smart" weapon systems. The cruise missile and other systems such as the Firefinder artillery-locating radar, the Pershing II terminal guidance radar, and a wide range of mission planning simulators and command and control systems all depend upon DMA digital products.

All military units, from infantry patrols to the most modern weapons systems, require products of the Defense Mapping Agency. Requirements for digital data (even from the users of traditional map and chart information) are becoming more and more sophisticated. Users will need up-to-date cartographic information without waiting weeks or months for the normal distribution process to work. Modern users will require electronic map and chart information quickly, and will also require access to the digital database for supportive cartographic information.

Techniques that could be applied for presentation of digital MC&G information on electronic displays are available today. A three-dimensional perspective scene is relatively simple to output, either to an electronic display device or to a lithographic printing process. Since most electronic displays cannot replicate the resolution of the lithographic process, an analysis of the two outputs might lead one to conclude the electronic display to be a degradation of the paper product. However, the creative potential of the Electronic Chart becomes apparent when one considers the dynamic applications available for real time interaction with the displayed data sets. Parameters of a displayed scene can be changed by means of simple inputs, and real time sensor information can be overlaid and combined with the MC&G digital data base for timely and flexible responses to user needs. Thus the EC becomes a cost effective and versatile tool capable of supporting a multitude of modern day mapping, charting, and planning requirements.

MODERNIZATION

DMA is in the midst of a complex modernization program to achieve greater productivity and to meet increasingly sophisticated digital data base requirements. DMA will have on line in the 1990's a virtually all-digital production process, developed through utilization of high-speed computers and computer data exchange systems. The rapid emergence of extremely sophisticated computer technology has been the catalyst for this revolution of cartographic techniques. Computers are being applied to all phases of the production effort, from source analysis to product generation. DMA is also developing advanced digital workstations to handle digital, graphical, and textual data. These workstations will be the foundation for DMA production in the 1990's. This all-digital production system will dramatically reduce the present labor-intensive compilation processes inherent in manual map/chart production, resulting in significant productivity increases and improved user responsiveness.

The all-digital production system will be geared towards a "product independent" digital data base to include cartographic feature data required to support all DMA paper, film, and digital products. Working at advanced digital workstations, DMA cartographers will develop the digitized data for insertion into a cartographic data base or for lithographic or digital product generation

With the modernization, DMA has begun to generate the required data base(s) to support user digital requirements. If DMA cannot, because of limited production resources, provide these digital data, users will be forced to collect their own or, in some cases, even to do without. Users who generate their own digital data, whether by customizing existing data bases or digitizing paper maps and charts, run the risk of inadvertently introducing errors into their applications. Errors in the data could lead to faulty system development and subsequently negate an entire development or deployment effort. Furthermore, data bases generated by multiple users could create a standardization nightmare for any subsequent data exchanges. Thus, it is imperative that DMA succeed in its modernization program and provide accurate, up-to-date cartographic data to its users. DMA should then consider the most effective distribution and display methodologies for digital information. Standards for both the telecommunications and the electronic portrayal of the digital data need to be addressed. Telecommunications requirements are being addressed by DMA, but are outside the scope of this paper.

ELECTRONIC CHARTING

Electronic output is a logical follow on to the development and initialization of a DMA digital data base of MC&G information. What do we mean by an Electronic Chart (EC)? The standard product would be MC&G data provided by DMA for display on a screen. This would provide the controlled base over which the user would then superimpose information from his own real-time sensors. A real time radar image superimposed over a DMA data set would considerably enhance the usefulness of the EC display. Any uncharted or misplotted features would be immediately identifiable since they would be displayed simultaneously with the DMA data.

As an example, one could use an EC display as a vehicle navigation system where automated steering and collision avoidance become practical for the real time alignment of the vehicle's position. Another example of an EC is the digital hydro chart currently operational in the Navy's PHM class Hydrofoil Ships. Coastal charts in digital form are stored in the ships' computers. They are skewed to match real-time radar returns of the coastline against the stored charts. Then when a hostile reading, such as a fast-closing ship, comes up, this data is displayed on the screen with a warning bell or whistle, and evasive maneuvers follow. There can be numerous variations of this scenario. Aircraft applications are obvious, and ground forces are moving rapidly into this area as well. A company commander in the field will continue to need DMA paper maps, but the commander back at battalion HQ will be using a computer display.

DMA must support the commanders of all armed forces with data at the same accuracy they now get with paper maps and charts. Users will need basic DMA map data on that display and will need to enhance it with real time information, possibly even in a three-dimensional format. EC users will need to be able to select instantaneously from a number of maps or charts and then, in turn, be able to zoom in rapidly on the area of concern.

EC PRODUCT REQUIREMENTS

DMA does not make an EC digital product, per se. DMA generates the Mapping, Charting, and Geodesy (MC&G) data that provides the metricity to support the interaction with user on-board real-time sensor imagery.

The U.S. Army, the Air Force, and the Navy are independently developing a number of electronic display systems to support planning and tactical operations. These are in response to individual service requirements and will all require DMA to provide the digital MC&G data necessary to drive them. For example:

> The U.S. Army has developed the Digital Topographic Support System (DTSS) to support Corps, Division, and above planning and operations. DMA digital data base requirements include a 1:50,000 scale product, including terrain analysis overlay data, to support operational areas and a 1:12,500 product to support testing, training, and development areas. Other systems include an All Source Analysis System (ASAS) for intelligence fusion, a Battlefield Management System (BMS), and a Night Navigation Topological System for helicopter navigation support.

Air Force developments include the Automated Mission Planning System (AMPS) to support pre-mission planning on a simulator and to provide on-board threat navigation support, the B1B simulator, and the optical disk store for the AV-8B Harrier aircraft.

The Navy has implemented a Hydrofoil Collision and Tracking System (HYCATS) on its PHM class hydrofoil patrol vessels. Displayed are ships position and threats overlaying DMA-provided coastal and harbor data. Other systems requiring medium scale DMA digital sources (bathymetric, shorelines, threats, etc.) for input are the Submarine Advanced Combat System (SUBACS) and the Aegis system. Aegis is projected to be operational in 1987 and will provide a 42-inch screen for the real time display of task grouping, shorelines, and hazards, and will support anti-aircraft defense.

Each service requirement will have to be fully understood by DMA cartographers in order to generate a useful digital product for maximum exploitation on each proposed display device.

DESIGN GOALS

An ideal goal in the design of EC products to support these developing service requirements is that the systems they are displayed on be user friendly and responsive to the requirements for which they were developed. Operations controls must be easily learned, the hardware ruggedized for stand alone field operations, and the system hardware and software be easily maintained. DMA input into the EC product would be standardized MC&G digital data sets capable of being transformed into highly readable and understandable displays. The success of any EC program development will only be as successful as DMA's capability to provide the data to drive it. The success of the total EC program requirement will be driven by the success of the standardization effort. Unless DMA can generate a standard for universal use, the cost of production and the subsequent transformation of the data sets to support specific user requirements could become prohibitive.

Generic display components of EC systems must be standardized as much as possible to reduce production, maintenance, and training costs. Display hardware design and content must strive for graphic simplicity. Complex displays can be erroneously interpreted and used by human operators. This could negate the effectiveness of the product design. The EC should also operate with minimal operator intervention. Hardware and software parameters should be designed to display current situations unless expressly overridden by the operator. A display where the vehicle position remains centered on the screen would be a useful format, since it offers the maximum view of the surroundings. This would also allow the user to maintain some of the perspective currently designed into the DMA paper products.

MC&G DATA SETS TO SUPPORT ELECTRONIC CHARTS

The basic coding dimensions for symbolic representations in a static mapping format are shape, color, and size. Symbols in a dynamic mapping environment can exploit color and be caused to blink, fade, highlight, vibrate, etc. Blinking, for instance, can be exploited in electronic charting applications when an object is of target interest or when an occurrence will cause a change in a real-time display.

In support of new and upcoming navigation and guidance display systems, DMA must be able to provide adequate digital data bases that describe a variety of types of MC&G information. In addition to the basic requirements for traditional MC&G feature data at an increased resolution and level of detail, there will be requirements for time-varying information such as texture, thermal, and near-infrared properties; population and traffic density patterns; atmospheric weather data; etc. All attributes will be required in DMA Feature Analysis Coding Standard (FACS) feature descriptors. Data from these various sources must be fused in the EC display so that information can be quickly assimilated and reduced to meaningful conclusions in command and tactical situations.

For an EC to be effective, the digital data requirements necessary to drive the product need to be identified and validated prior to actual system development. Digital data production can then keep pace with system development for implementation of an operational product. The digital MC&G data set required to support the proper portrayal of the data on an electronic chart display would include:

Feature types and attributes (FACS coding) to adequately represent the required environment.

Symbology to assure feature types and conditions displayed will have universal interpretation to all users.

Data density sufficient for the optimal representation of the product requirements.

Scale to realistically portray the essential information.

The most important aspect for successful implementation of an electronic chart concept is standardization. This means adopting a standard for symbology, feature contents, density, scale of display, resolution of display, etc., and, most importantly, a means to ensure that any developed standard can be universally implemented.

Variable resolution requirements could make the EC product a challenge to derive from standard data bases. If the data base is indeed product independent, data captured at a single scale, not coincident with the EC product, would require the application of either generalization or enhancement refinements. DMA currently produces products that could require both applications, e.g, for navigation scales (Harbor and Approach Charts) that could have extremes of scale above and below the data base scale. Developers, as well as users, must be aware of the danger of using digital data at a larger scale than that at which it was collected and validated for insertion into the data base. To do so would imply a greater level of accuracy to the data, which could lead to disaster if accuracy is a critical requirement. How to insure that this will not occur is a critical issue to be worked.

EC PORTRAYAL

Electronic charting has the potential to provide new approaches to mapping problems that have been virtually unsolvable on hardcopy media. An example is the problem of representing superimposed surfaces (i.e., sea surface, ocean bottom, and objects in the intervening space) on the mapping medium. Another example could be the concurrent and detailed depiction of air space, flight corridors, and terrain.

Electronic charts should resemble paper maps and charts with minimum feature density. This traditional appearance would facilitate acceptance of the EC by the user and make it easier to use. To insure that all EC systems receive the same basic information for portrayal, it is essential that the digital data be derived from the same data source using standard algorithms whenever possible.

Electronic maps will allow for flexible viewing. Perspective views of terrain can be extremely useful in terrain visualization where viewpoint is critical. Interaction with perspective views will allow users to specify altitude, azimuth, and distance, as well as to zoom, pan, and rotate.

Animation of the data can provide a way to show predicted or real-time changes in the geographic area of interest.

The display should permit the user to tailor the screen contents to his liking by means of scale change, zoom and pan, deselection, etc. Moving map capabilities would allow users to travel within a mapped area, zooming in for large scale information and zooming out for a birds-eye view, to support cross-country and trafficing requirements.

The results of 3-D perspective models, predictive models, and quantitative calculations performed by the computer can be displayed on electronic charts. Based on terrain analysis information, an overland route for an army tank can be generated and displayed in real time. The display would minimize trafficability risks (off road soil conditions, tree diameters, water barriers, etc.) and exploit other factors (navigable roads, etc.) subject to the constraints of the parameters of the tank. Time, distance, and most importantly, a wealth of stored geographic information too complex for adequate display in two dimensions, can be factored into the computations for the real time display.

Reference grids can be useful additions to displays. Electronic charts can generate virtually any kind of grid overlay to enhance the usability of the displayed data.

We must remember that the effects of an EC product may not all be positive. It may be one thing to have a 1;20,000 scale paper chart and quite another to permit only the display of a 5-inch sized CRT section of that chart at any given time. As an example, Harbor and Approach Chart scales are selected in such a manner as to provide maximum aid to navigation. The CRT-displayed portion would eliminate a vital aspect (total picture) of the chart, and a selectable scale capability would only partially solve this problem.

Data resolution can also vary within the digital EC product. This can cause scaling difficulties if a vehicle, such as a ship or tank, moves into a product area digitized at a different scale. Whether moving from a large scale to a small-scale area, or from a small-scale to a large-scale area, scale selection is difficult. Multi-scale presentations can cause feature distortion (jagged or sparse depending on the scale), and the display of data at a higher resolution (than digitized) implies positional and contextual accuracies that cannot be supported by the data. Windows within displays, side-by-side displays, and superimposition are potential remedies to these problems.

DISPLAY TECHNOLOGIES

The applications described above will depend upon available display system technologies. DMA is currently committed to CRT technology for internal softcopy exploitation of its digital data bases. Note, however, the user potential for 1990's EC utilization of other flat panel devices. The two technologies emerging as the leaders are liquid crystals and electro-luminescence.

Liquid Crystal Displays (LCD) are the most mature of the flat panel technologies. Because of their poor contrast and viewability, however, LCDs have made few inroads into large-screen applications. These afflictions should largely disappear with the advent of new techniques for activating the display. Reductions in cost will hopefully come with large-volume production (as in the case of the personal computer market driving the development of the optical disk).

The electroluminescent (EL) panel is also becoming competitive in the market place. With its pleasing amber radiance, light weight, and slender profile, EL displays have already made their debut in the personal computer market. ELs are active, emitting their own light so they can be viewed under almost any lighting conditions. ELs also have higher contrast, better resolution, and much wider viewing angles than LCDs. The panels' ruggedness, low power consumption (relative to CRTs), light weight, and good viewability are drivers for military (army and avionics) interest in this technology. Advancements expected include the advent of full color, new high-contrast designs that will make the displays readable even in sunlight, and advanced driver electronics that make panels more compact and energy-efficient.

Future growth of large-area flat panels will probably depend on a reciprocal relationship with portable computers. Advances in display technology should improve the appearance of portables, while any increase in portable sales would accelerate demand for displays.

SUMMARY

Display technologies and database capabilities are now mature enough to support producing electronic charts. The ultimate success of an EC will depend upon proper identification and validation of product digital data requirements prior to actual system development. This will allow DMA product support to pace system development.

Another important aspect for successful implementation of the electronic chart concept is standardization. Standards will ensure and preserve the critical significance of DMA supplied data. Digital data in a universally accepted standard format will provide DMA the capability for greater flexibility and increased responsiveness in support of user requirements.

Softcopy display design for an EC product is highly dependent upon the capabilities of the output device. Resolution constrains symbology and textual display designs. Electronic charting, however, expands the possibilities for symbolization and display manipulation through the dynamics of CRT technology. The capability for exploitation of a digital data base in conjunction with these dynamic displays will allow customized presentations geared directly to user needs for optimal user satisfaction. The user will be able to use DMA digital data in an EC of his own making. Note, however, that the dynamic capability for interacting with and changing the display contents can also pose dangers to users with non-cartographic backgrounds since inadvertent user manipulation and deselection of specific data (sets) could contaminate the user perspective designed into the total EC product and subsequently promote erroneous interpretation of the data.

Finally, a critical component in support of new planning, navigation, and guidance systems is the ability for DMA to actually provide adequate digital databases containing the required MC&G information optimized for electronic displays. Ultra-high resolution databases will be required in the 1990s with additional feature descriptors and resolutions. Current production resources at DMA limit high-resolution data to small geographic areas of interest. The required production of large area, high-resolution databases will be unattainable without both adequate source data and enhanced automated feature extraction techniques. The success of electronic charting applications of DMA MC&G data will only be as successful as our capability to load and maintain the digital data.

DMA is addressing the tremendous problem of automating digital data and chart production processes in the modernization program. More and more users will be demanding more and more sophisticated digital data, and ECs could allow DMA a means to exploit new approaches to satisfying those user requirements in the 1990s.