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Use of Imagery and GIS for Humanitarian Demining Management

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Abstract

In the fall of 1996, the Center for Geographic Information Science (GIS) at James Madison University became involved in a Department of Defense project, under the auspices of Essex/Star Mountain, Inc. This project evaluated the data needs and data management systems for humanitarian demining in the Third World. In particular, it focused on the information needs of demining in Cambodia and in Bosnia. During the first phase of the project one team of researchers attempted to identify all sources of unclassified country data, image data, and map data. Another team of researchers evaluated commercial off-the-shelf computer software packages for the management of geographical information. The result was a design for the kinds of data and the kinds of systems necessary to establish and maintain a database to be used as a humanitarian demining management tool. The second phase of the work involved acquiring the recommended data and systems, integrating the two, and producing a demonstration of the system. In general, the configuration involves ruggedized portable computers for field use with a greatly simplified graphical user interface. This system is supported by a more capable central facility equipped with Pentium workstations and manned by technical experts.

Keywords: humanitarian demining, geographical information systems, GIS databases, aerial imagery in GIS, demining management

1. The Existing Problem

The removal of landmines and unexploded ordnance from former battlegrounds has become big business. On almost every continent, the civilian population is subjected to unseen dangers from unexploded ordnance, the effects of which are well publicized. The classic summary statement of this worldwide tragedy is that it directly affects sixty-eight nations, and that it produces a civilian casualty every twenty-two minutes. The unnecessary civilian deaths and the sad, crippling injuries have been repeatedly documented in the media. However, landmines have other important effects that are also incapacitating to the nations where bygone wars occurred. Landmines deny large areas of land for economic use. They create barriers to the efficient development of the transportation infrastructure in these typically third-world countries that are trying to recover after a conflict. Due to the danger and uncertainty, they also discourage investment and staff commitment by world development agencies and engineering firms. Even U.S. soldiers who are specially trained for demining are not permitted to remove mines for humanitarian purposes. Instead, they "clear" mines to support current military operations.

For these reasons and more, the commercial humanitarian demining business is growing, as is the movement to ban the production and use of landmines worldwide. International programs to assist Third World nations with humanitarian demining are in progress in more than a dozen countries. In some cases, these programs are small and local. In other cases, they are regional or national in character, and involve significant amounts of resources, technology and management. Typically, these larger programs involve teams of deminers being sent to the field from a regional center. Efficiently doing this implies a level of organization involving long supply lines, extensive training programs for field personnel, scientific and technical backup, the use of computers and other modern tools, and some form of database.

A well-structured spatial database is essential for successful demining management. The database is basically used to keep track of minefield locations and boundaries, mine accident locations, frequency of injuries, cleared areas, areas under production, etc. This could be imagined as a kind of computer spreadsheet. However, this simplified statement ignores the many other kinds of data that also need to be considered: political boundary lines; the transportation infrastructure; the locations and capabilities of emergency support facilities, such as hospitals and communication centers; the topography and land cover; the uneven distribution of population, the geology and soils, as well as the terrain trafficability for vehicles of various types. The spreadsheet model also ignores the fact that the managers and planners want to be able to access and analyze their data *geographically*. The computer tool that allows the visualization of all of these layers and their geographic analysis is the Geographic Information System (GIS).

The effort to employ these technologies to assist with in-country humanitarian demining programs is only in its infancy. There are many problems, *cost* certainly being a primary one. A second problem is the complexity of the system for a field user. In order for the system to supply the *functionality*, it must be flexible and extensive in its capabilities. This automatically implies complexity, which requires considerable training and relatively educated end users. For demining programs that will eventually be transferred to the host country, this may be too great an expectation. One way around this is to write custom software that is greatly simplified and contains only those functions and capabilities needed for that particular job. Another approach is to customize existing, standardized, off-the-shelf software for the end user. The James Madison University demining team took this latter approach.

2. The Search for Data

Under the support of the Department of Defense (through the Star Mountain Corporation of Alexandria, Virginia) for Cambodia and Bosnia, general searches were conducted for country data, aerial image data and map data. Search methods included extensive use of the World Wide Web, visits to various libraries and centers (such as the Library of Congress), and extensive telephone interviews. The country data sources were assembled in bibliographic form, that is, as references rather than as hardcopy or softcopy documents. The map and aerial image data were first researched with respect to such factors as availability of coverage, date, scale, and cost.

Map coverage of Cambodia and Bosnia comes from a great variety of sources. Small-scale historical maps with various themes were found. The CIA, for example, has produced, through the years, many thematic maps in these two areas of the world. Some useful commercial and tourist maps also were sought out and used in connection with this project. However, by far the most important map input came from the National Map and Imagery Agency of the U.S. Department of Defense (NIMA, formerly Defense Mapping Agency, or DMA). When needed, the Department of Defense provided these maps in softcopy and hardcopy mode.

Standard aerial photography is not freely available in much of the Third World, as it is in the United States. Obtaining new mapping photography is, of course, a possibility. However, many factors, especially cost, make this a doubtful resource for humanitarian demining operations. Also, weather conditions in these typically equatorial and tropical (or eastern European) countries make aerial photography difficult. In some cases, that could mean that countrywide coverage of a nation could take years, until every portion is caught under cloud-free conditions. The primary purpose of the aerial imagery is not to find landmines, but rather, to serve as (1) a map substitute, (2) a method of rapidly updating maps, and (3) a visualization tool for the ground conditions.

Although small scale, recent commercial satellite imagery is universally available for land areas. Moreover, it costs a small fraction of comparable aerial photography. Commercial satellite imagery is already in digital raster form, making it ideal for a computer database. Because of the hyper-altitude nature of the photographic platform, image displacements due to topography are minimized. Consequently, this kind of aerial imagery was judged to be the most appropriate for a cost-effective humanitarian demining operation. Accordingly, the following commercial image data sources were investigated: LANDSAT (U.S.), SPOT Panchromatic (France), SPOT Multispectral (France), IRS 1-C Panchromatic (India), IRS 1-C LISS-3 Multispectral (India), KVR-1000 (Russia), TK-350 (Russia), and Space Imaging Cartera Data (U.S.).

3. The Search for Software

Prior to beginning a search for appropriate software, some assumptions had to be made. One of these was that the Pentium PC would make the best platform for this type of work. The reasons for this decision were many: most common availability and supportability worldwide, great ease of use when compared with UNIX workstations and other high end machines, much lower cost, wide choice of GIS software packages, availability of ruggedized hardware for field use, and compatibility with a variety of other equipment, including some pocket computers and pen-based machines. A second assumption was that some portion of the software should be installable and easily useable by field personnel relying on portable computers. This implies either very simple software or complex software that is modified to appear simple and easy to learn.

Detailed information on a wide variety of GIS software packages was obtained. This information was categorized and compared to provide the basis for conclusions. A further input to this process was the review of the various packages, as found in the literature. The basic facts and capabilities of the GIS packages were summarized in a large spreadsheet to provide some overview for judgements.

4. The Recommended Design for the Spatial Database and the GIS

Detailed comparisons were made among the various data sources and software vendors. Although conducted by separate working groups, the two evaluation processes, could not be isolated from each other because of the need for the software to fit the kind of data to be selected. That is, a large fraction of the GIS industry is based on *vector data*, with only slight capabilities to actually analyze *raster data*. Another portion of the GIS sector is based primarily on raster data and has very limited vector capabilities. However, the most readily available and appropriate data for humanitarian demining, mostly in the Third World, consists of *raster* information: digital satellite imagery and scanned topographic maps. From this, a variety of kinds of raster and vector data can easily be produced. Vector data is usually much more economical in its storage space requirements and is typically faster on the computer for many GIS analysis operations. An important part of the GIS design is that the manifold and complex input data sets should be researched, ingested, verified and condensed at a technical support center before they are installed on the ruggedized field computers or simply written to CD-ROM to be sent to the field.

The input data sources deemed most essential for the core of the database consist of easily available, commercial satellite imagery and U.S. military topographic maps. Each of these two graphic data sources is totally standardized, available for most of the inhabited world, suitable for immediate insertion into the computer database, understandable by a very wide variety of persons, and finally, characterized by some form of updating and maintenance by the producer.

Concerning the *aerial image* data layer, many combinations and scenarios were considered. In terms of pixel size on the ground, these options ranged from the 30-meter pixels of the Landsat Thematic Mapper data, down to the 1-meter pixels of the Lockheed/Martin Space Imaging data expected to be available early next year. To provide a basis for comparison, standard large-scale orthophoto coverage was also evaluated. Despite efforts to shift to newer kinds of satellite data that offer higher resolution, the immediate availability of data, the price, and other considerations led to the conclusion that the classical approach is most cost effective. For over a decade this approach has involved the use of Landsat Thematic Mapper data (30-meter resolution) for its color bands, and Spot Panchromatic data (10-meter resolution) for its much finer spatial resolution on the ground. Image fusion methods for these two kinds of data have been in place for many years and, in fact, have become almost one-button operations. The result of those operations is typically a new, ground-referenced image file with the fine ground detail of the French data, but in color. This makes a very useful graphic layer in the GIS. It can be used as a visualization backdrop for other layers, as a source for the screen digitizing of new thematic layers, as the primary input for a multispectral land cover classification map, or for the purpose of updating topographic maps. Although the files are large, they are suitable for a wide variety of data reduction techniques for storage purposes. They can also be very easily subset into smaller images by province, grid square, or some other method of subdivision.

Concerning the *map data*, although there were many input products discovered for Cambodia and Bosnia, one cartographic source outshined all others in terms of its relevance and quality. This was the 1:50,000 Tactical Line Map of the National Imagery and Mapping Agency. This is a rigorously edited, totally standardized, national mapping product, which is available off-the-shelf for many areas of the world. It is now being produced as a standard hardcopy topographic map and as a computer raster file called an ARC Digitized Raster Graphics Coverage, or ADRG. These ADRGs have a five-meter pixel size and can easily be brought into a GIS or an image processing system. They are, of course, internally georeferenced so that they can be displayed over the aerial imagery or any other layers of the database.

A very difficult decision had to be made concerning the *software* to prepare the database and to use it in the field: Should the system be *raster* or *vector* based? After much discussion, it was concluded that some features of each were absolutely necessary. Accordingly, the design calls for *both* raster and vector capabilities at the support center, and a very simplified display capability in the field. This implies maximum flexibility in the kinds of data that can be imported and in the kinds of operations that can take place to analyze and combine the data and prepare it for field use. It makes the support center more complex, but the field operations much simpler due to the thorough preprocessing of the data.

The raster GIS selected is the ERDAS Imagine package. It was chosen over many others because of its fine capabilities, world-wide availability and support, and built-in compatibility with the vector systems selected. Imagine supports an extremely wide range of image processing and GIS capabilities. Its import and export routines are also particularly robust and extensive. Thus, its use in future demining management projects will insure the greatest flexibility in terms of the kinds of input data that can be easily handled.

The vector GIS for the humanitarian demining management system is the ArcInfo package from Environmental Systems Research Institute, or ESRI. It is the dominant GIS software used world- wide. In addition, the firm has had a close working relationship with ERDAS over many years. This means that the transfer of data in either direction is greatly expedited. Because of the complexity of this powerful group of ArcInfo modules, the company has also produced a related, greatly simplified program called ArcView. It is designed to allow a much wider variety of clients to view maps and data, to manipulate them somewhat, and to print them out with great ease. In the current design, Imagine and ArcInfo would be used to ingest and prepare the data for field use. Then field personnel would use ArcView on the Demining Support System (Star Mountain Corporation) ruggedized portable PC.

Using the ESRI programming language, Avenue, the version of ArcView prepared for field use, has been greatly condensed in terms of its graphical user interface. When the software wakes up, a simplified, customized ArcView screen is visible. It allows certain basic operations to take place almost with the push of one button on the newly designed toolbar. For example, a user can display any of many different data layers for a desired geographical location. He or she can also take basic measurements from the screen of such things as distances, areas, and ground coordinates. New geographic features can be added in the field by simply digitizing on the screen with the map or aerial imagery in the background. The user can then combine the desired layers into a standardized map composition and print it. A beginner requires minimal training or two days at most.

5. Conclusions

In conclusion, the system design involves a well-equipped, high technology support facility that does not need to be located in the nation where the demining is taking place. This support facility acquires and integrates the standard data types described above, as well as any other desired coverage. Appropriate data fusion and data reduction take place at the support facility. After quality control, the data set for a portion of the project area abroad is written to CD ROM and sent to the site. This CD is immediately useable with any Pentium PC. Its initial location would be at a regional demining headquarters, such as Sarajevo or Mostar in Bosnia. It could then be taken along to the work site as appropriate. Available on the computer in the field would be enhanced, color satellite imagery of ten meters ground resolution, NIMA 1:50,000 digital topographic maps at five-meter resolution, as well as overlays and regional maps as appropriate. Because all materials are standardized and georeferenced, the various data layers can be viewed and printed by field personnel very easily in virtually any combination. The combination of high functionality and ease of use in the field have driven the current design.

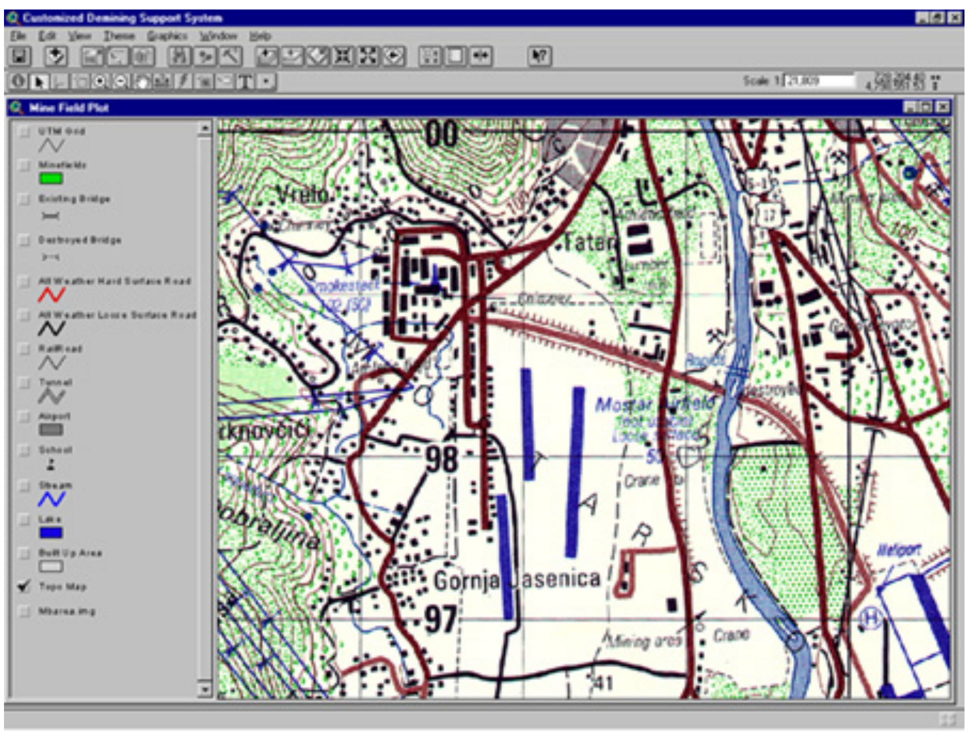

Figure 1: The customized ArcView user interface for humanitarian demining management (James Madison University and Essex Corp.)

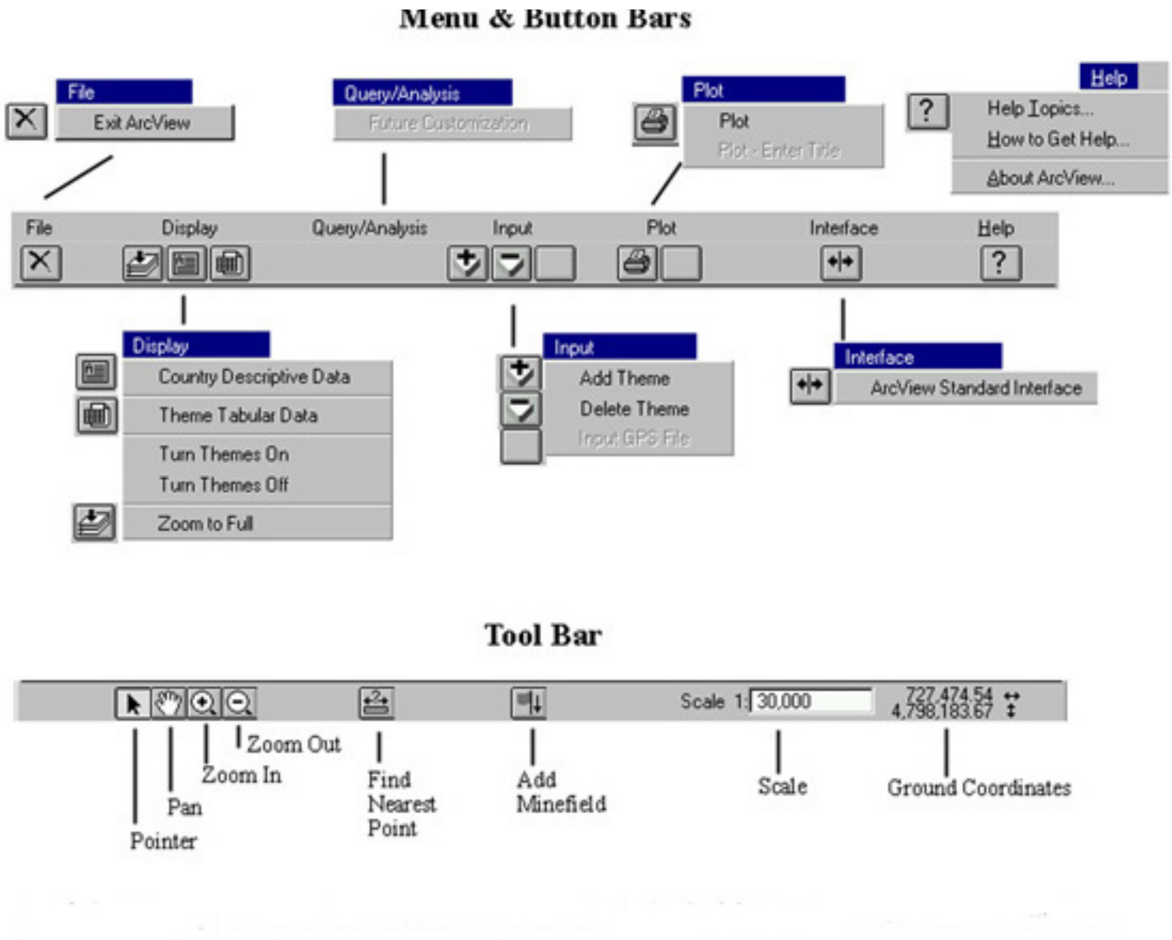

Figure 2: Components of the customized ArcView user interface for humanitarian demining management (James Madison University and Essex Corp.)