MILITARY BASE PLANNING USING GEOGRAPHIC INFORMATION SYSTEMS TECHNOLOGY

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BIOGRAPHICAL SKETCH

Mr. Drinnan has designed, developed, implemented and marketed Mapping Information Management Systems for more than ten years. He is currently Manager, Advanced Projects for Synercom Technology, Inc. He is SIG Co-chairman for Geoprocessing for URISA, Member of NCGA's Technical, Research and Standards Committee and co-author of the APWA CAMRAS reports. He is a member of ACSM.

ABSTRACT

Planning for a military base is done in a regulated command environment over a contained geographical area. Contingency plans which radically change the base in a very short time are also developed and maintained. Over 65 different maps may be in one master plan. The effect of change is posted on all the affected maps and incorporated within the contingency plans.

Geographic Information System (GIS) technology provides the planner tools to manage both the spatial and temporal aspects of plans and changes. By developing integrated parametric units, the data may be maintained in an integrated manner and many of the maps generated automatically by aggreating the parametric units. The temporal aspect of the system may be studied by developing the union of integrated parametric unit coverages from past years and future plans. Changes may be made to the collection of data rather than each map.

By incorporating specialized reporting capability within the system capability, much of the regulation paperwork may be generated automatically. This paper explores the use of GIS within the particular environment of military base planning.

INTRODUCTION

Military base planning includes the recording and analysis of spatial data. Geographical Information System (GIS) technology provides the automated tools to effectively manage the spatial data. By combining spatial data with data that is naturally stored as lines and symbols, a complete digital plan of a military base may be stored and maintained on a Mapping Information Management System (MIMS). MIMS is a broad system including GIS technology as a subset. The integration of spatial, inventory data, utility, planimetric and topographic data into a single digital plan offers the ability to relate these data quickly in ways that would be impractical in a manual drafting system.

This paper proposes a technical approach to the conversion, use and maintenance of spatial data within the framework of a totally integrated data base. Geographic Information System (GIS) is defined and basic (not all inclusive) requirements are described.

To relate different coverages of spatial data an integrated parametric unit approach is proposed. Examples of the use of the basic GIS algorithms and integrated parametric units are developed for data conversion, analysis, temporal data management and maintenance. Special reporting requirements are discussed briefly.

Examples have been drawn from data captured and tested on the Synercom INFORMAP II and Environmental Management Information System (EMIS) software products. INFORMAP II is a proven MIMS system with many different installations throughout the world. EMIS is the GIS subsystem of INFORMAP II and is derived from the Harvard Laboratory for Computer Graphics and Spatial Analysis Odyssey program.

MILITARY BASE PLANNING MAPS

Planning for a militray base is done in a regulated command environment over a contained geographical area. A regulated command environment requires that procedures and regulations be strictly followed and that extensive reports and forms accompany each change. The contained area restricts the size of the problem although the size may be large for the scale of maps produced (Vandenburg Air Force Base is 100,000 acres, China Lake Naval Weapons Center is 1,100,000 acres, for example). The constrained, usually crowded, area makes the planning more difficult.

A master plan may include over 65 different maps at several scales and all with different content. The maps are developed by composite techniques utilizing the planimetric and topographic maps as the base. Many of the maps are a geographically oriented inventory of facility elements rather than classified spatial data. The integration of facility maps with spatial maps provides unique analysis opportunities that are difficult to accomplish in a manual drafting system.

GEOGRAPHIC INFORMATION SYSTEMS - A DEFINITION

The term Geographic Information System (GIS) could be used to describe any system which processes geographically oriented data. However the term was first used to describe systems which analyze data that is spatially organized and topologically defined. This data is generally represented by collective polygons (or grid cells) forming a coverage. A coverage is a map with each area classified and the boundaries delineated. Output results are portrayed in two or three dimensions with the data classified and thematically presented. GIS includes the ability to determine the interrelationship between several coverages. This definition has been widely used in the literature and will be followed in this paper. The scope of this paper is vector oriented data and not grid cell data.

The term Mapping Information Management Systems (MIMS) represents a broader system including planimetric, topographic, facilities mapping, GIS and other mapping technologies in an automated computer graphics system. Both GIS and MIMS associate attributes with geographical location entities. GIS is concerned with the relationship between homogenous areas defined topologically while MIMS includes attributes for specific elements such as the facilities making up a public works system as well as GIS, spatial type entities. MIMS manage both line and symbol entities as well as spatial entities. MIMS systems produce high quality cartographic products. See Reference 1.

The analysis capabilities within a GIS include the ability to:

1. Determine and manage polygons from arbitrarily digitized line strings.

2. Associate attribute data with each polygon.

3. Determine zones and areas about line and symbol entities.

4. Perform a union of two coverages to form a new coverage with all the informational content of the original two coverages.

5. Thematically represent the classified results of coverages.

6. Determine areas by classification.

7. Aggregate polygons of similar classifications into a single polygon.

These are basic capabilities and numerous additional capabilities are commercially available in GIS products. This paper will show examples of how each of these analysis capabilities may be used within the military base planning application.

INTEGRATED PARAMETRIC UNIT

An integrated parametric unit is the result from unioning two or more coverages. Each parametric unit has homogenous attributes from the original coverages. An integrated parametric unit means that small inconsistencies in the representation of common boundaries such as roads, hydrology, soil changes, etc. have been removed by the digitizer and by the system. Otherwise the integrated coverages are dominated by small meaningless sliver polygons. The advantage of consistent development of integrated parametric units from highly correlated data is that the inconsistencies are systematically removed and analysis can usually be done by examining the attribute data associated with each parametric unit rather than reprocessing the polygon data.

DATA CONVERSION

The military base plans are derived from aerial photography, existing map sources, inventory records, field surveys and other sources. The source documents have different scales, accuracy levels, and confidence levels.

Spatial data is a set of lines forming polygons with some notation of the classification of each polygon. The conversion of buildings into topological correct data, so that a GIS can analyze the data, illustrates the data conversion technique:

1. Using stereo photography and classical stereo compilation techniques determine the boundaries of the buildings. The user is not required to digitize the building outline in any particular order.

2. Using the GIS technology determine the building polygons. The GIS system will recognize each line segment that makes up a polygon and will cause end points that are close to each other (within a tolerance) to coincide. Doubly digitized lines, dangling lines and other error conditions are recognized and recorded.

3. The GIS technology determines a logical sequence number and centroid.

4. The user, from existing records, corresponds the centroid sequence number and the attribute information. This can be done at an alphanumeric CRT.

5. Map products may then be produced by classifying the buildings based on the attributes (building use for example) and thematically presented the buildings using crosshatching, gray scale, halftone and color representation capability. Figure I provides an example of the final product.

Modern GIS does not require the user to directly define the polygon boundaries, digitize the polygons in any particular order or associate left and right attributes directly with each polygon boundary segment. Removing these requirements reduces the data conversion effort substantially.

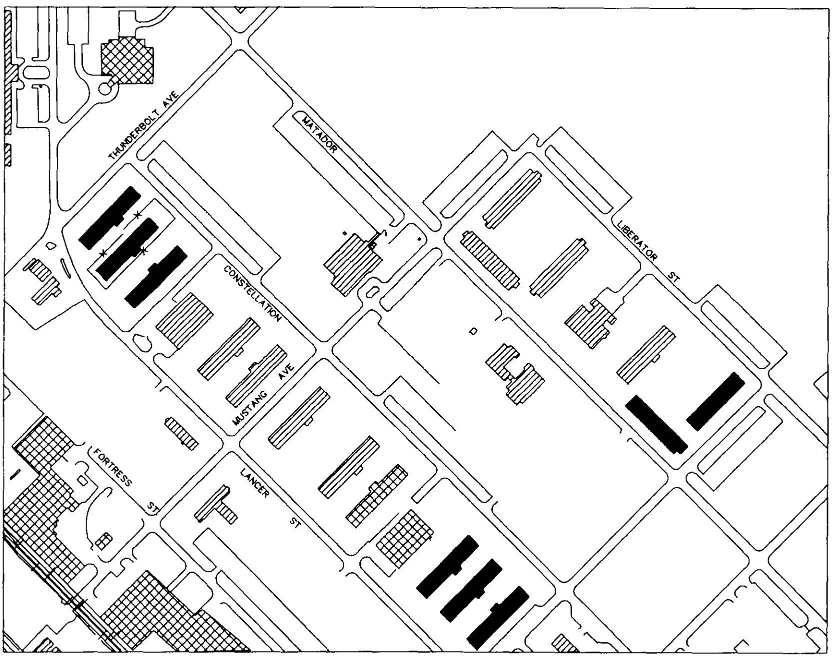

Figure I

Buildings Converted to Topological Polygons, Classified, and Crosshatched

OTHER POLYGON DETERMINATION

Zones such as approach-departure zones, obstructions, habitat limits, and historical sites are determined geometrically based on data that has already been entered into the digital master plan. A GIS system can determine polygons in the following manners:

1. Fixed distance about a specific point such as a historical site.
2. Fixed distance about a line. Suitability zone about a road for example.
3. Fixed distance about a facility or structures such as hazard zones about a munition dump.

The integration of inventory, planimetric, topographic and special data into a single digital data base combined with the GIS technology provides for the generation of these polygons automatically.

Topographic data are used to generate slope, aspect ratios, viewing angles, etc. These values may then be classified and polygons derived to form a coverage.

HIGHLY CORRELATED DATA

Each type of spatial data forms a coverage. The buildings, hazard zones, soil, etc. form separate coverages. Many of these coverages are highly correlated. For example, roads, hydrology, soils, vegetation, and land use often have common boundaries. Some of these coverages are more accurately captured than others. The coverages may be unioned together to produce integrated parametric units (sometimes called integrated terrain units). An integrated parametric unit is a coverage itself with the data classified by the attributes of the contributing coverages. The generation of integrated parametric units usually proceeds from the most accurate data to the less accurate data. For the example above, the roads and hydrology will be captured accurately from a stereo photography. To develop the land use coverage, the accurate location of the roads and hydrology should be considered. There is a wide spectrum of techniques to produce integrated parametric units from essentially manual drafting techniques to the GIS doing most of the resolution of the data. The manual techniques are manpower intensive; the completely automated techniques require careful determination of tolerances and precise digitizing. In a digitizing environment utilizing interactive graphics feedback a compromise between the extremes is most effective. One procedure is:

1. Include the roads and hydrology as potential boundaries in the coverages.
2. Assuming a separate source for the land use, place the land use source on the digitizer and determine the non-linear transformation from the land use to the accurate compiled map by recognizing common points. If the system has cursor tracking, then digitizer location may be reflected on a display of the digitized data.
3. Digitize the land use boundaries. When a natural boundary exists digitize up to it or slightly over it. There is no need to snap to the natural boundary since the polygon building logic will do that subsequently. The natural boundary is also not redigitized or otherwise traced. The user can always view the interrelationships on the graphics CRT.

4. Execute the GIS polygon building algorithm to determine the polygons and automatically snap the boundaries to the natural boundaries.

5. Resolve any inconsistancies that the GIS has found using the graphics CRT.

6. Assign land use codes to the computed centroids. An alternative is to digitize and classify the centroids at the time the boundaries are digitized.

7. If a number of polygons are homogenous across the boundary, then the polygons can be aggregated to form a new set of polygons which do not include the natural boundary when the land use does not change.

Producing high cartographic quality maps requires specialized display techniques. This is not only the classical thematic tones that GIS usually supports but also the display of lines that form mutual boundaries. For example the hydrology may be displayed in blue while the land use in green. For mutual boundaries the hydrology will have precedence. If a land use map is required that does not include hydrology, the same line in the data base would be green. This is easily accomplished with a system whose displays are driven by representational tables external to the converted data base. It is even easier if the system supports multiple display modes. See reference 2 and 3.

ANALYSIS USING INTEGRATED PARAMETRIC UNITS

The results of analysis of spatial data is either a tabular report listing access by classification or some form of thematic map where each classification is displayed uniquely in either quantized steps or continuous graduations. If all the related data has been integrated together, then each polygon attribute record captures each polygon it belongs to within each coverage. Thus any form of analysis merely involves operations on the attribute data and does not require processing of the polygon data. If a thematic result is required the classification as an output of the analysis is stored in the attribute record for the polygons and the display logic formats the output referencing this classification. Complex classification procedures may be easily developed.

The land use suitability results (Figure 2) is an example of the analysis that can be done using GIS algorithms and integrated parametric units. The map was derived as follows:

1. Develop 1984 Land Use Coverage by digitizing the boundaries and programatically determining topological polygons.

2. Develop Historical site and Woodpecker Habitat restricted areas using bounding radius about the historical sites.

3. Develop Military Land Use Map coverage including a buffer about the roads.

4. Develop Equipment Limits and Erosion Factor of Soils. This coverage was derived from other coverages.

5. Union the 1984 Land Use coverage with the Historical Site coverage.

6. Union Military Land Use with Equipment Limits.

7. Union the coverages determined in step 5 and step 6. Derive a classification based on the classifications in the original coverages. At this step a full integrated parametric unit coverage has been derived.

8. Aggregate the polygons based on the classification levels.

9. Assign symbolization to each classification and produce the final product (Figure 2).

This example exercises all the basic GIS technology requirements.

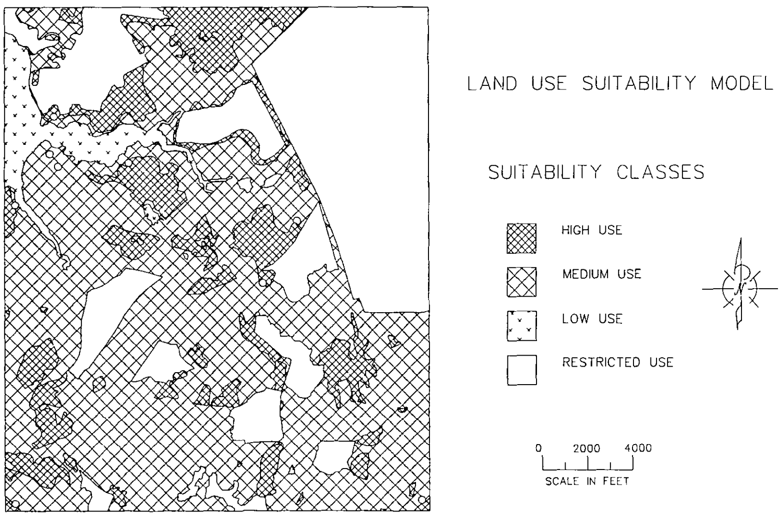

Figure 2

Land Use Suitability Analysis Final Product

TEMPORAL ANALYSIS

Military base plans require historical as well as planned improvements and contingency plans. These plans become an integral portion of the data base and thus proposed changes can be considered in relation to other plans and contingencies without additional effort. One approach is to define a coverage of the planned changes. For example, the five year plan for building changes could be developed as follows:

1. Copy the existing buildings and attribute data to a new coverage.

2. Set the change flag for each building to no change.

3. For each change modify the attribute file to indicate the change and include the expected date of the change.

4. For new construction add the building to the new coverage.

To produce a map of the status at any given time select from the plan coverage the changes to be completed by that time and then overlay it with the existing condition. The data that has changed (torn down, built, modified) can be highlighted by color or other symbolization. As a change is implemented the as built condition is placed in the plan coverage, selected separately from the other changes in the plan, overlayed with the existing condition, and the existing condition updated. Yearly the existing conditions are archieved in coverage form so a historical record is kept. A change map may be produced at any time.

REPORTING REQUIREMENTS

In a regulated command environment the reporting requirements are extensive. By utilizing an integrated parametric unit approach including proposed changes and past usage, many of the reports may be automated. For example the Strategic Air Command Form 246 (Figure 3) documents the area presently used, existing usable facilities and facilities planned for future use by use category for a particular Air Force base. This may be developed by examining the integrated data for each building.

CONCLUSION

The Geographic Information System (GIS) technology has numerous applications for military base planning. It offers rapid data conversion, extensive analysis capabilities and graphic as well as narrative reports.

Developing the base plan utilizing integrated parametric units recognizes the interrelationships of some coverages and resolves data conversion inconsistencies as the data is captured. The result is a more accurate data base supporting many analysis requirements quickly. Specialized reports and temporal analysis are readily automated.

By integrating data derived in point or line format with the GIS data, new coverages may be easily defined. By displaying these other maps in conjunction with the GIS output, a higher quality cartographic product may be produced.

The Synercom products, EMIS and INFORMAP II, provides an integrated system technology to support mapping as well as GIS requirements for the militray base planner. The integration of this technology broadens the use of the digital military base plan.

S.A.C. 246

SUPPORTING DATA PROGRAMMED INSTALLATION DATE REPORTS CONTROL
END MISSION REQUIREMENTS JACKSON AFB, CTG 19-Oct-84 HAF-PRE(AR) 7115

SECTION A

1 CATEGORY	2 NOMENCLATURE	3 AGENCY	4 UNITS	5 QNTY. REQ.
721312	DORM AM PP/PCS-S	SAC	SF	146665

6 EXT. UNUSABLE	7 EXISTING USABLE	8 NOT IN INVENT	9 CURRENT DEF.
118001 SF	152664 SF	0	5999 SF

10 PROGRAMMED AMT.	11 PROG. DEFICIENCY	12 PROG DEFICIENCY COST
0	0	0

SECTION B COMPUTATIONS AND SOURCE DOCUMENTS

1 COMPUTATION OF REQUIREMENTS — 2 AUTHORIZATION OR SOUR.

COMPLIMENT 18 MEN EQUALS 5700 SF — AFM 86-2, PARA 16-10C

MOBILITY EQUIPEMENT STORAGE 3150 SF

SECTION C

EXISTING FACILITIES PRESENTLY USABLE OR PROGRAMMED TO BECOME USABLE

FACILITY NUMBER	SCOPE		STATUS VAC	STATUS OCC	DISPOSAL ACTION PROCESS YES	DISPOSAL ACTION PROCESS NO
0301	17159	SF	X		X	
0302	17159	SF	X			X
0304	16116	SF		X		X
0305	17159	SF		X		X
0307	17159	SF		X	X	
0309	16090	SF	X			X
0311	17159	SF		X		X
	118001	SF				

2 EXISTING USABLE FACILITIES

FACILITY NUMBER	SCOPE		STATUS VAC	STATUS OCC	EXISTING CODE	PROGRAMMED CODE
0327	26035	SF	X		0	
0328	25185	SF		X	2	
0329	26035	SF		X	2	
0331	25039	SF		X	1	
0332	25185	SF		X	1	
0333	25185	SF		X	1	
	152664	SF				

SECTION D FACILITIES PROGRAMMED FOR ANOTHER USE

FACILITY NUMBER	SCOPE	FUTURE NOMENCLATURE	FUTURE CATEG.	FUTURE CODE

REMARKS

COORDINATOR
UNIT COMMANDER

ORGANIZATION
305 CSG/SP
CATEGORY CODE
721312

SAC 246 SYNERCOM INFORMAP II SYSTEM

Figure 3

Example Report Derived From
Integrated Building Data

REFERENCE

1. Drinnan, Charles H., Vertical integration of small and large scale mapping systems, Third Annual Alaskan Conference for Computer Graphics and Geoprocessing, September 1982.

2. Drinnan, Charles H., Design considerations for mapping information management systems to support multipurpose cadastres, Computers Environment Urban Systems, Vol. 9, Pergamon Press 1985.

3. Drinnan, Charles H., Data base considerations in small scale mapping, Electronic Imaging, June 1984.