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DIGITAL MAPPING, STATUS AND APPLICATIONS

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Introduction

Digital mapping systems have different origins, application scope and design philosophy. Some were developed to supplement data acquisition equipment, some are single purpose systems answering specific user requirements, e. g. various land information systems, and some are based on a general purpose interactive graphics system (CAD/CAM) with application software for cartographic or engineering mapping. Raster image processing systems have emerged as a result of increasing availability of remotely sensed data from satellites. Geographic information systems (GIS) employ topological data structures in order to perform spatial analysis of point, line and aereal features. Also available are raster graphics systems for cartographic editing and plotting.

As the applications of digital geographic data are becoming more common, the advantages of combining various mapping technologies are becoming apparent. Both raster and vector data acquired from variety of sources can be incorporated in the database on basis of a common geodetic reference and can be linked to one or more non-graphic databases, providing multipurpose mapping and analysis functions for a variety of users.

The latest systems for digital mapping indeed integrate significant features of different categories of mapping systems into a general mapping and information management system. At the same time, the emergence of new generation 32 bit minicomputers such as MicroVAX II and proliferation of Personal Computers has forced the price of systems to levels acceptable to smaller users such as medium size municipalities and service bureaus.

The following discussion will focus on some recent developments toward integration of various mapping disciplines on the basis of an interactive graphic system, illustrated by practical examples. Complete system description can be found in (1).

Data collection and conversion

Cost effective data capture is crucial to digital mapping. A much larger percentage of maps would be digital today, were it not for the high conversion cost or the impossibility to complete the data conversion within some practical time limits. New technology can play a major role in solving the problem. Interesting technological advances have been achieved recently in the areas of remote sensing, scanning, and photogrammetry.

Remote sensing

Modern GIS systems and mapping systems can translate remotely sensed raster data into vector databases and interface with image processing systems of other vendors. Intergraph, for example, supports DIPIX, MDA and ERDAS. The process involves data transfer and the conversion of raster to vector format and vice versa.

Current developments, however, integrate image processing capabilities, using any of Intergraph's 1048 x 1280 resolution colour terminals, with standard interactive graphics functions. Effective processing and display of raster data requires an array processor; Intergraph uses a propriatory 64x64 bit programmable Graphics Processor parallel-ported directly to the terminal. The software includes typical image processing functions and allows simultaneous display and manipulation of raster and vector data.

The applications are numerous, for example: the digitizing and editing of vector data from raster image, edge extraction and vectorizing or aiding supervised classification of image data based on known information in the vector database.

Scanning

Hardware scanner technology is relatively mature. Drum or flat bed electro-optical scanners such as Scitex or Optronics have the required accuracy, resolution (25 micron) and area (up to 1 x 1 m) for use in scanning existing maps or aerial photographs. Solid state scanners employing LED arrays, charged-coupled devices or charge-injection sensors are likely to be used for low resolution scanning in the future. Intergraph uses Optronics X4040 microdensitometer, which is also

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suitable for high resolution plotting.

The challenge of automatic digitizing lies, of course, in developing software for reliable and cost-effective feature recognition. Today's software is capable of recognizing contours, polygons, stream networks and predefined text and cartographic symbols. Software to detect features on a typical cadastral or Ordnance Survey type map is under development by several companies. Utility distribution networks are less suitable for scanning. In all cases, the quality of the source documents plays major role.

Fully automatic and reliable recognition of random map features is, however, unrealistic. A practical approach seems to be to optimize the operator's involvement through encoding the realiability of recognition by colour, automatically queueing up all situations not meeting the recognition criteria, and presenting them in detail, one after another, to the operator for review.

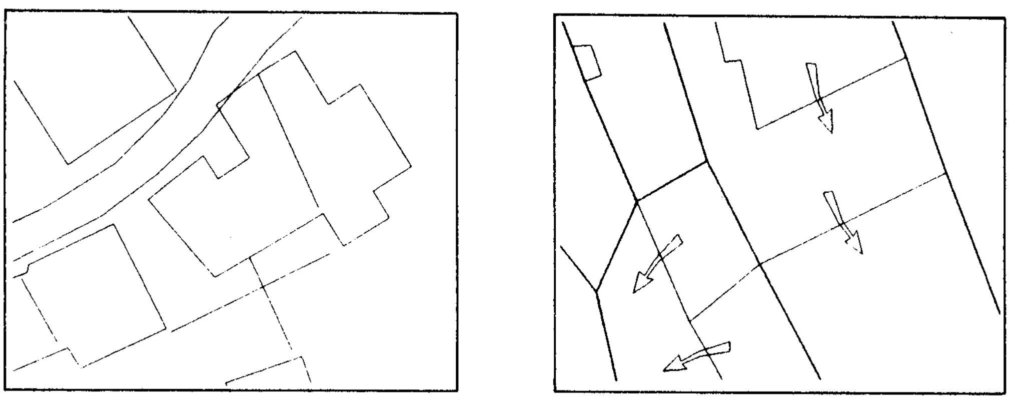
The X4040 is interfaced on-line to the graphic database, using again the Graphic Processor to off-load the CPU and to allow immediate pre-processing of the data. This integration eliminates the cumbersome manipulation of magnetic tapes which is typical for off-line systems. The combined effects of the online approach and the optimization of interactive editing is best illustrated by the productivity achieved by the Automap II system of the Australian army, see below.

It remains to be mentioned that some applications are satisfied by the original unprocessed raster data, or a vectorized, but unedited, raw vector file used as a background image for the user's overlay.

Photogrammetry

Intergraph pioneered the integration of interactive graphics and photogrammetry, with the introduction of Intermap photogrammetric workstation and optical superimposition in 1982.

Intermap provides an on-line connection between the digital encoders of an analog instrument and the graphic database. Being a full-fledged interactive graphic terminal, it displays the database's current status and allows immediate interactive editing, enabling errors to be captured at source. Working through simple menus defined for each specific project, the operator can introduce any desired intelligence into the database with no extra effort: from simple assignment of levels to symbol generation, feature coding and even the analysis and storage of computational results in an associated non-graphic database. Interactive functions such as "snapping" to existing data points help produce a clean database and reduce the cost of editing. The following example shows typical digital file produced off-line, and on-line, using Intermap.



"Snapping" to data from the previous model displayed as a reference file also eliminates the need for edge matching later on. Over 100 Intermap workstations have been installed so far, used primarily for large scale mapping , but also for medium and small scale topographic and planimetric mapping (2).

Application: Scanning 1:50000, 1:100000 scale maps

RSSS System Objectives

* CAPTURE A COMPLETE MAP BY SCAN DIGITIZING
* SCAN, EDIT AND TAG AT THE RATE OF 2 MAPS/8 HOUR DAY; OR 40 HOURS / MAP USING 10 WORKSTATIONS
* CAPTURE COLOUR MAPS, PENCIL AND INK COMPILATIONS, AND FILM SEPARATES BY SCAN DIGITIZING

AUSTRALIAN ARMY
NOV. 1984 FUNCTIONAL TEST RESULTS SUMMARY
FOR 1:50000 AND 1: 100000 SCALE MAPS
SCANNED AT 25 MICRONS

SEPARATION TYPE	SCAN TIME IN HOURS	BATCH TIME IN HOURS	INTERACTIVE TIME IN HOURS
RELIEF			12
DRAINAGE			10
CULTURAL			8
VEGETATION			12
HIGHWAY			7
TOTAL	3.0	5	49
	(2.7 maps/day)	(1.6 maps/day)	(1.6 maps/day)

NOTE: 'DAY' = 8 HOUR SHIFT

INTERACTIVE TIME - RECENT IMPROVEMENTS

PROCESS	GAIN IN HOURS
* AUTOMATIC VEGETATION TAGGING	4 - 6
* AUTOMATIC CONTOUR TAGGING	2 - 3
* IMPROVED CENTERLINING	1 - 1
* IMPROVED CHARACTER RECOGNITION	0 - 1
TOTAL GAIN	7 - 11
TOTAL INTERACTIVE TIME	42 - 38
	(1.9 maps/day - 2.1 maps/day)

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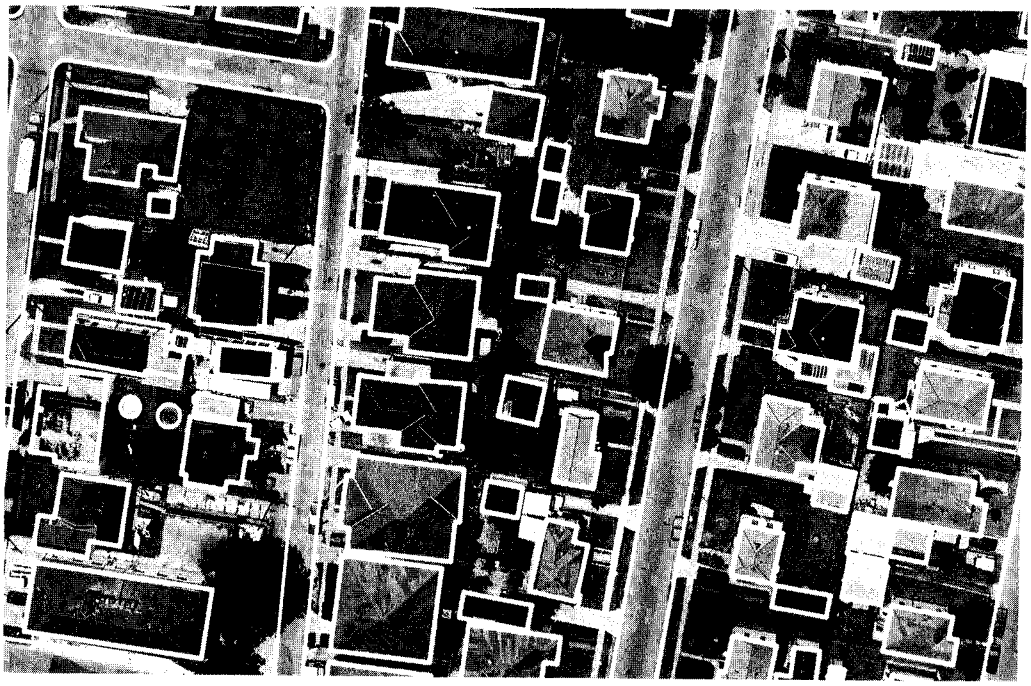
<u>Optical superimposition</u> allows direct visual comparison of the active digital file with the photo model. The data being overlayed comes from the system's graphic database and is therefore not restricted to the file currently being compiled, but can include files compiled previously or files created by means other than photogrammetry (e. g. scanning). Optical superimposition is obviously most interesting for map revisions. Productivity and quality improvements achieved through optical superimposition have been reported by, among others, the Australian Army (3) and KLM Aerocarto (4).



Optical superimposition

Digital map compiled on an Intermap-Galileo G7 workstation.
Courtesy of Istituto Geografico Militare, Florence, Italy.

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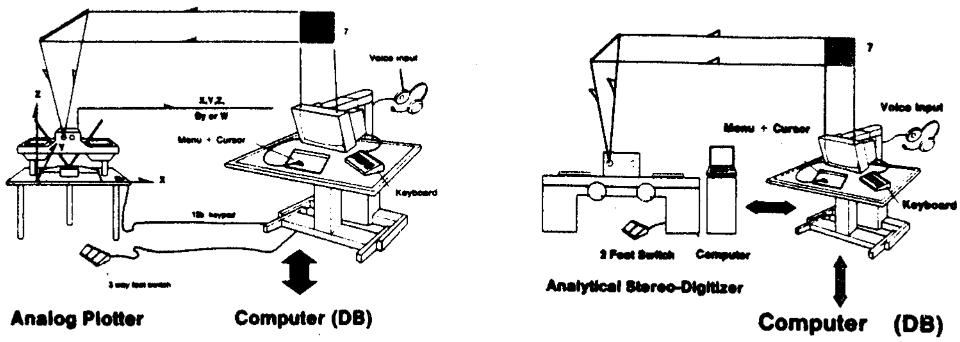
The next step in integrating photogrammetry and digital mapping was connecting Intermap on-line to an analytical instrument, again including optional superimposition. Two way communication allowed the operator to drive the movement of the photo stages from the Intermap workstation (5).



The latest step is the complete integration of an analytical instrument and a graphic workstation into one unit. Nicknamed ZIP for the Zeiss-Intergraph-Project, the Intermap Analytical workstation uses a 15-inch colour monitor to display system control information in the field of view, in addition to superimposing digitized data or any other graphic file. It further includes a unique two-handed cursor as a means of controlling movement of the stages, and controlling software and digitizing map features. The software includes a fully automated calibration package, formatting for aerial triangulation, and orientation software.

Database

The key aspect of a multi-purpose mapping and geographic information system is the possibility of integrating graphic data with non-graphic databases into an intelligent structure, which allows spatial analysis and cross-referencing between layers. With the increasing availability of remotely sensed data in raster format, it is further becoming necessary to allow layers of raster data be mixed with vector data in a unified database.

Graphic data

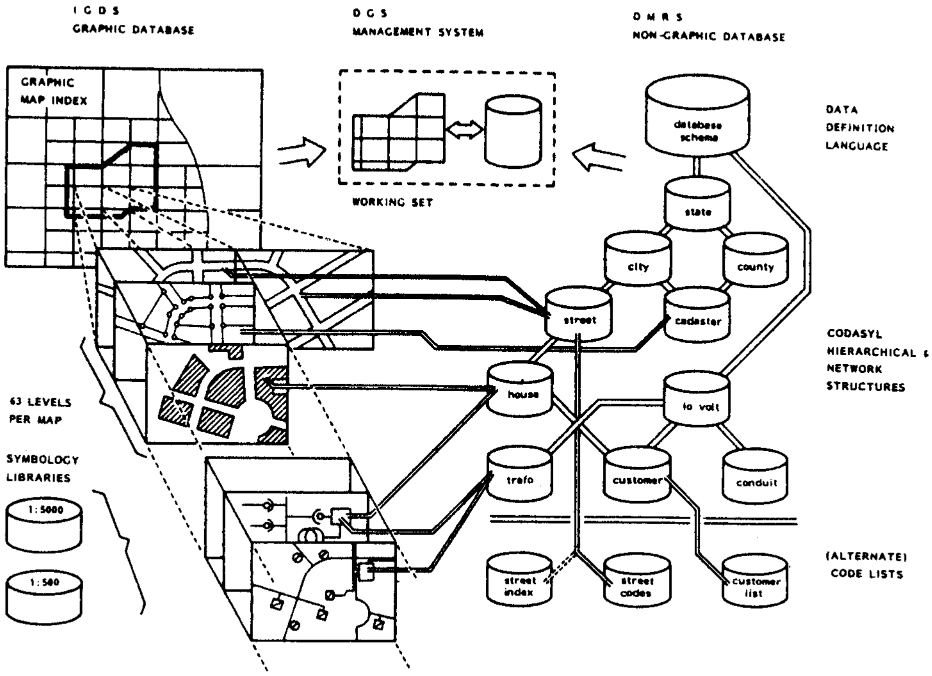
Intergraph system integrates all three types of data. Graphic files are sequential, with hardware-controlled access by geographic location or area, combined with data selection by layers, graphic characteristics and status flags. This approach allows fast interactive response, which topological structures usually lack. Although internally segmented, the graphic database appears geographically continuous to the user.

Non-graphic data

The Data Base Management System is utilized to define logical relationships between map elements and to store associated non-graphic information. Classical hierarchical, and, more recently, network models are being replaced by relational structures. Networks allow fast searches and data retrieval along predefined pointers, but require redesigning when changes to the structure are needed. Relational structures achieve more flexibility by replacing hard relationships by comparing fields in attribute data tables. The process is relatively CPU-intensive, causing relational databases to become less effective with increasing volumes of data. Intergraph's DBMS combines relational access by dedicated hardware file processor with the possibility of defining navigational paths for frequently anticipated searches.

Raster data

Raster files can be included in the database either in their original "run length encoded" format, e. g. as retrieved from the optical scanner, or in a format generated and utilized by the Grid Data Utilities software. GDU serves either as a translator between vector and raster files or as a translator of remotely sensed data such as "landsat". Digital Elevation Models can be also defined in the raster format used by the Graphic Processor for dynamic display and analysis.



Reference files

In addition to the active file, up to 32 other graphic files can be called up for display and read-only access. This feature, essential in a multi-user mapping environment, creates the possibility for various organisations which share interest in the same geographic area, to build and maintain their own geographic files - whether vector, raster or DEM - based on common geodetic reference, and to use each other's data for reference purposes.

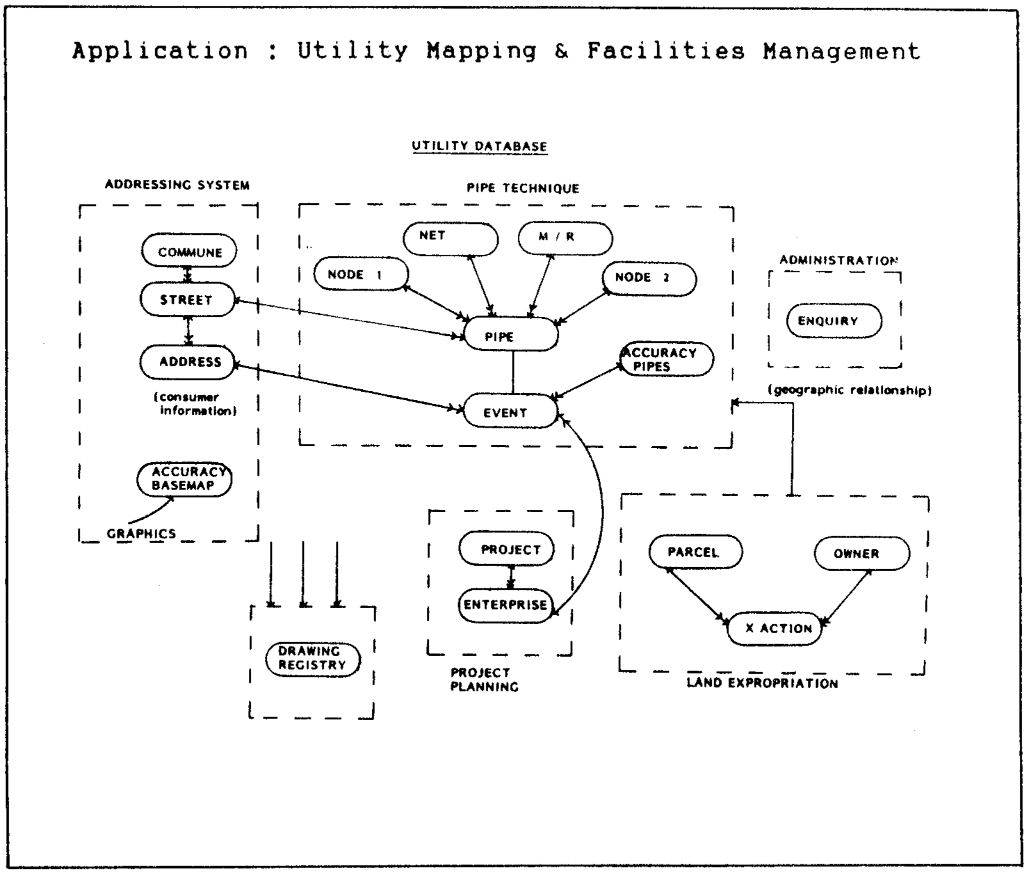
user n:	user 2:	user 1:	
		a	soil
	a	|	cadaster
	|	r	digital elevation model
	|	r	landsat
a	|	|	utility network
r	|	|	planimetry
r	r	|	topography
r	r	r	geodetic reference

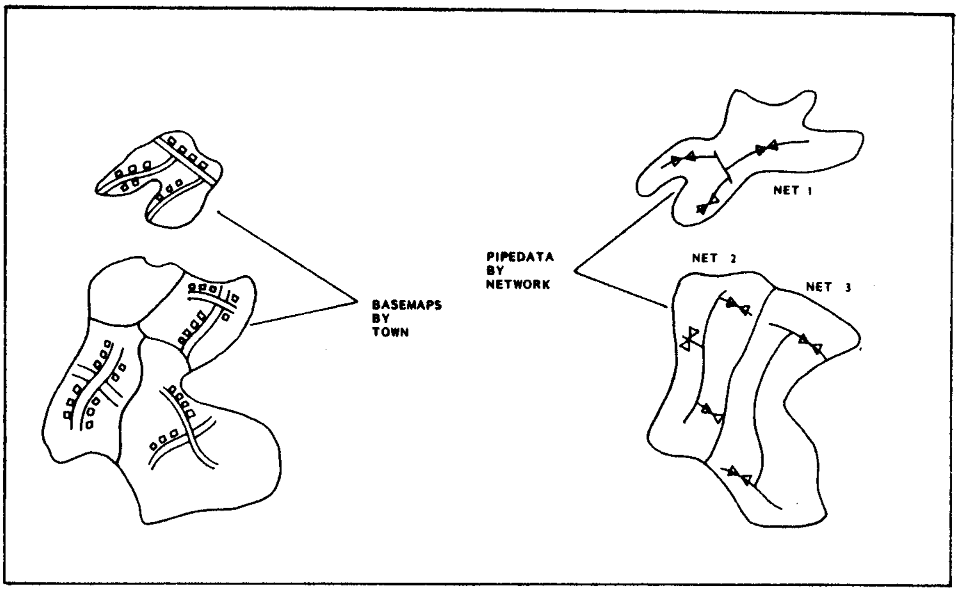
a - active file
r - reference file

Data access

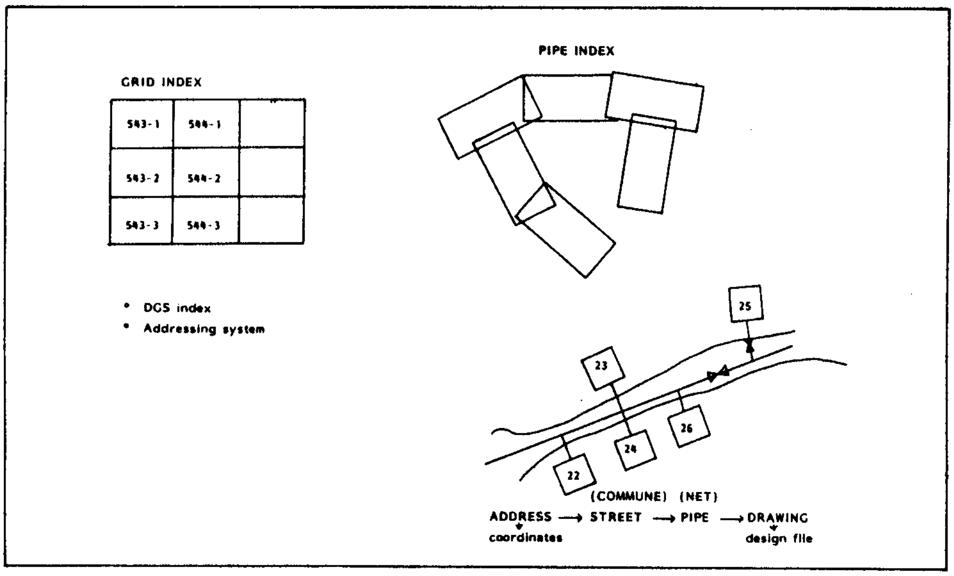
Using a system as an information management tool requires that the data can be accessed by any combination of geographic, logical or attribute criteria. In the following example of a utility basemap and distribution network database, typical access methods are:

- by postal address (range)
- street intersection
- item id
- item unique characteristics
- geographic location
- map grid, map number
- arbitrary polygon

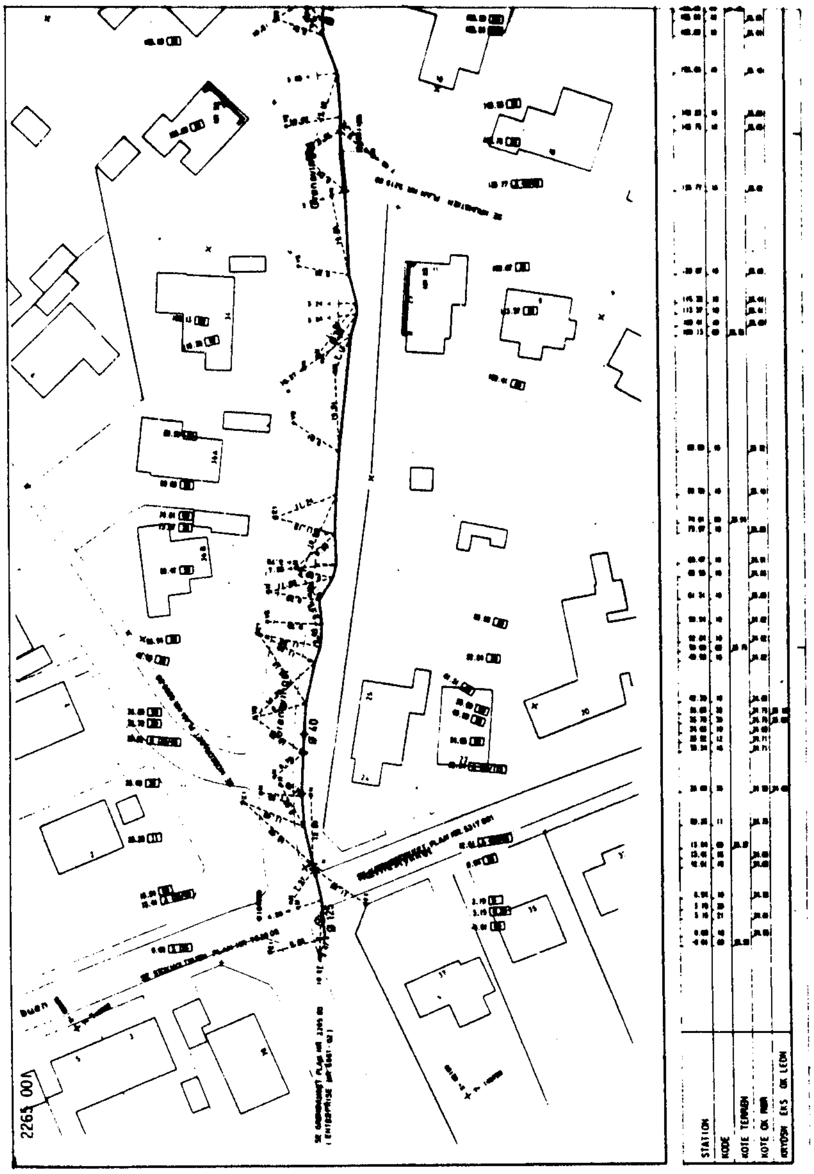




Graphic files are devided along
logical boundaries



Access to data through:
- map grid index
- pipe index
- postal address



Typical map output generated automatically from an alphanumeric terminal. The address range is the only input required.
Courtesy of Naturgas Fyn, Denmark

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Application: Cadastral Mapping

- Compilation of digital basemaps, whether from existing base materials or original surveys. Existing base material may include maps, survey notes, legal descriptions, or existing base materials represented already in digital format. Original survey data may be acquired employing ground survey or photogrammetric techniques.

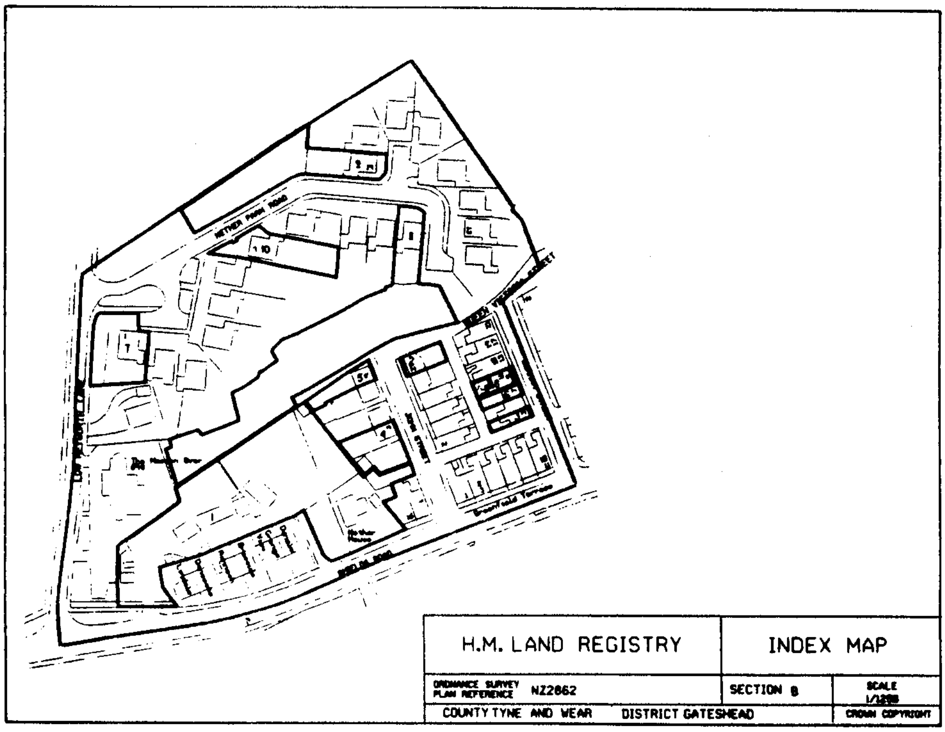
- Extraction of cadastral basemaps from topographic database, containing only the information relevant to the application. This process may include restructuring of unsuitably structured data for more sophisticated land database applications (e.g. creating polygons identifiable in the database, linkage of the parcels and buildings to the roads, etc).

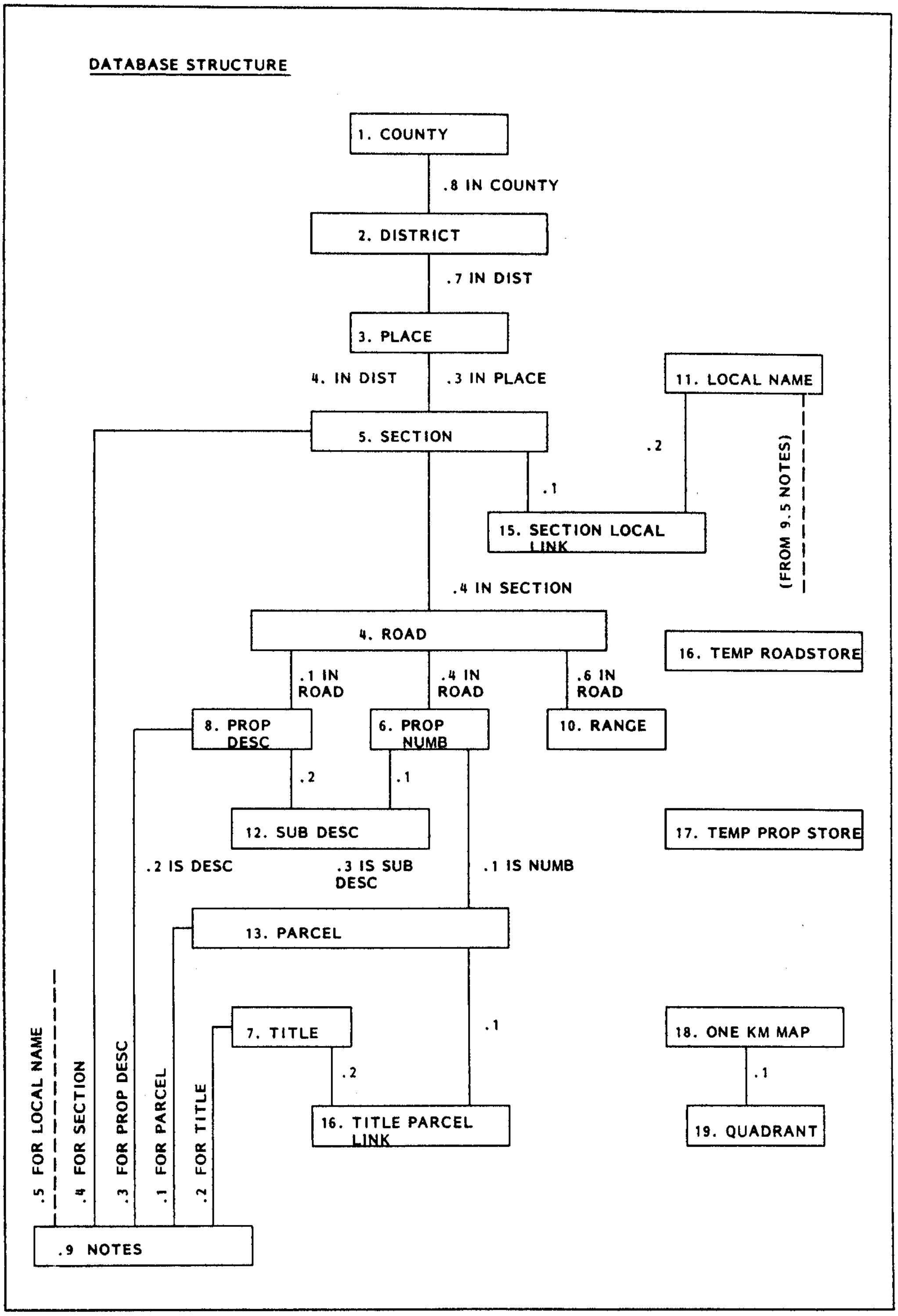
- Input and linkage of land registry information and other descriptive data with geographic location of the parcels.

- Enhancement and updating the geographic information whenever new survey details become available, or making changes in the registered parcel extent such as arise from mutation, or transfer of part of registered title.

- Enhancement and updating the descriptive data, or inclusion of a new class of information into the database.

- Restructuring the database according to the new demands.



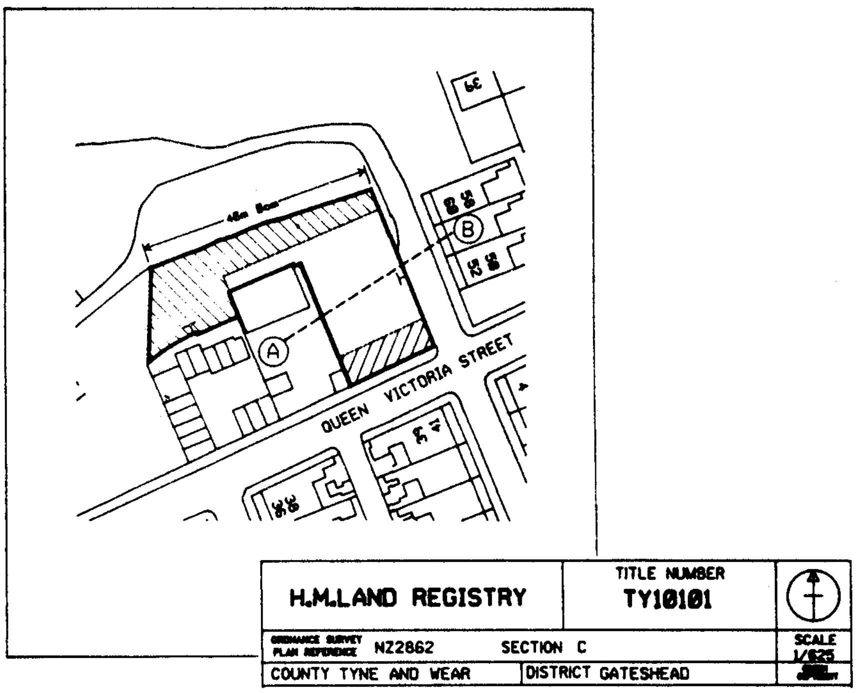

DATABASE STRUCTURE
1. COUNTY
.8 IN COUNTY
2. DISTRICT
.7 IN DIST
3. PLACE
4. IN DIST
.3 IN PLACE
11. LOCAL NAME
5. SECTION
.2
.1
15. SECTION LOCAL LINK
(FROM 9.5 NOTES)
.4 IN SECTION
4. ROAD
16. TEMP ROADSTORE
.1 IN ROAD
.4 IN ROAD
.6 IN ROAD
8. PROP DESC
6. PROP NUMB
10. RANGE
.2
.1
12. SUB DESC
17. TEMP PROP STORE
.2 IS DESC
.3 IS SUB DESC
.1 IS NUMB
13. PARCEL
7. TITLE
.1
18. ONE KM MAP
.2
.1
16. TITLE PARCEL LINK
19. QUADRANT
.5 FOR LOCAL NAME
.4 FOR SECTION
.3 FOR PROP DESC
.1 FOR PARCEL
.2 FOR TITLE
.9 NOTES

* Searches for user defined land information, or topographic data, and output such information to screen or hardcopy. For illustration purposes, a potential customer of a registered land may apply for copies fo the parcel plan and register, or a system user might ask for number of land parcels bought during a given period of time, the area and value covered.

* The graphic output of the individual land parcels may be produced on demand, at any desired scale and presentation. The plans may contain patterning, edging, annotation of registered extend of the boundary, colouring, coordinates of plot corners for restablishment of the lost boundaries, etc.

* Any section of the basemaps can be displayed, selected by property address, map section reference, etc. The dual screen of the Intergraph workstations provide for simultaneous view of the graphics and attribute data, e.g. when the map section is displayed on the right screen, with all cadastral parcel edgings and parcel numbers showing, a report on the registered title information associated with any parcel can be reviewed on the left screen, simply by identifying any of its elements with the cursor.
Area fill and colours can be added to visualize database attributes.
The dynamic panning and zooming allow to examine the details of a particular map section. Finally, a hardcopy of the selected map section can be output for permanent use.

* The database reporting system allows production of formatted reports on any combination of the stored land information (e.g. unregistered lands, tax appraisal, tax violation, etc).



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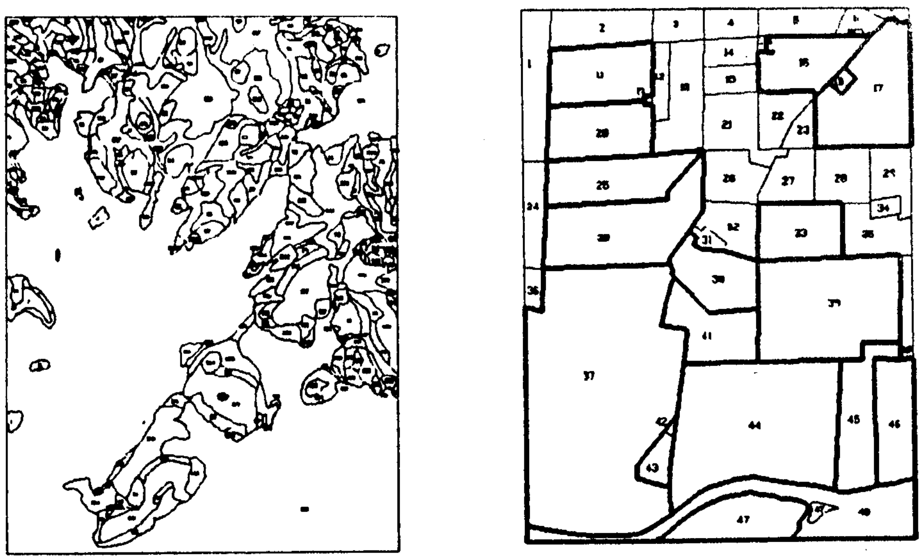
Spatial analysis

	point	line	area
point			
line			
area			

Most typical analytical functions of a geographic information system are spatial analysis of point, linear and areal features. Each square in the matrix represents a particular spatial relationship, e. g. the distance between points (p-p) or a point and a line (p-l), the line length within a polygon (l-a), or the intersection of two polygon coverages (a-a). Zones of equal distance around point linear and areal elements can be generated and included in the analysis.

Many of the above functions can be performed and are, indeed, easier to perform, with raster data. In the application examples below both the vector-based Graphic Polygon Processing Utilities (GPPU) and the Grid Data Utilities (GDU) software packages of Intergraph have been utilized to illustrate some of the analytical functions of a modern GIS system.

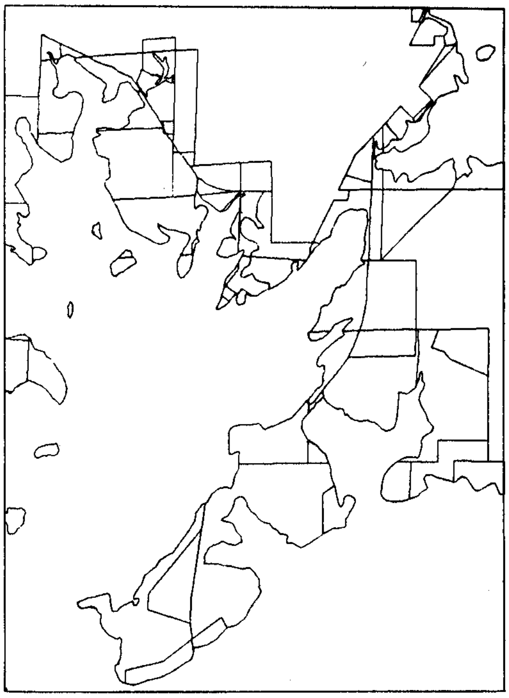
Application: Land Use & Resource Management



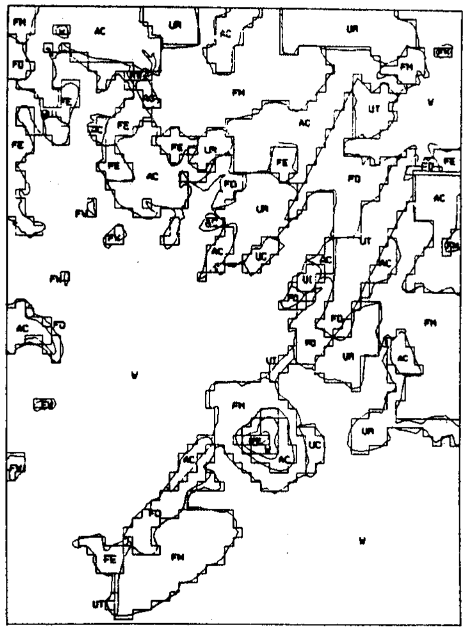
Soil mapping units

Acquisition tracts

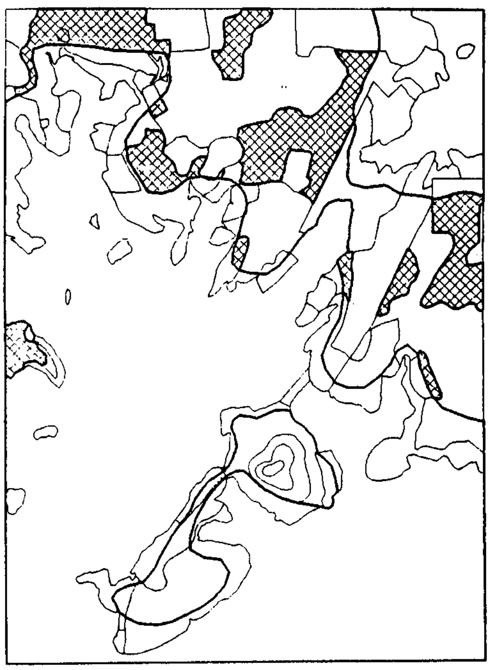
Examples of different area coverages



Forecast tracts subdivided by ownership, created from the intersection of forecast and acquisition tracts using "and" logic.



Polygon-to-Grid conversion and labelling (Grid Data Utilities)



REPORT ON FLOOD PRONE POLYGONS OVERLAY

DATE : 12/14/83 PAGE : 1

ORIGINAL PASTURE CROPLAND POLYGONS				FLOOD PRONE POLYGONS		
ID	COVER TYPES	AREA	~~~~	ID	RECODE ANALYZSIS	AREA
21	CROPLAND AND PASTURE	20 15	~~~~	1	VERY GOOD	20.15
29	CROPLAND AND PASTURE	9.99	~~~~	2	VERY GOOD	9.99
33	CROPLAND AND PASTURE	15 87	~~~~	3	LOW	13.71
23	CROPLAND AND PASTURE	9.20	~~~~	5	LOW	3.38
27	CROPLAND AND PASTURE	4 45	~~~~	6	MEDIUM	1.87
25	CROPLAND AND PASTURE	58 87	~~~~	7	LOW	0.39
25	CROPLAND AND PASTURE	58.87	~~~~	8	LOW	23.58
22	CROPLAND AND PASTURE	93 33	~~~~	9	FAIR	78.52
28	CROPLAND AND PASTURE	7.31	~~~~	10	VERY LOW	4.58
30	CROPLAND AND PASTURE	53.72	~~~~	11	FAIR	45.79
20	CROPLAND AND PASTURE	88 98	~~~~	12	MEDIUM	52.44
	TOTAL AREA	420.76				264.39

END OF FLOOD PRONE ZONE REPORT

Crop land and pasture outside flood prone areas (polygon overlay and analysis, attribute crosshatching)

Future trends

Coming developments are likely to further integrate remotely sensed raster data into mapping and geographic information systems on database and graphic terminal level.

Surveying and photogrammetry are becoming computer disciplines, forcing current manufacturers to shift focus and to acquire computer expertize in order to remain competetive.

Scanning will get cheaper and recognition algorithms more useful. Scanning services will get established in every major market or geographic territory.

PC-based, small systems will be developed challenging big established manufacturers of large systems. Engineering workstations capable of communicating with larger databases over a local area network, as well as working independently with a subset of data, will become increasingly popular.

Conclusion

Tools exist today for cost effective primary and secondary data acquisition, for the integration of planimetric, topographic, cadastral, land use/land cover and remotely sensed data, on basis of a uniform geodetic reference, and for spatial analysis across levels. Migration of these capabilities into new office minicomputer-based systems or even to terminal level will make digital mapping affordable at the lower end of the market.

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