DESIGN AND APPLICATION OF SPATIAL INFORMATION MANAGEMENT SYSTEM FOR CITY LAND ASSESSMENT

Genong Yu
Chengdu Subcentre of Agricultural Remote Sensing
CHENGDU 610066, P. R. China

Commision II, Working Group 3

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ABSTRACT

The development of geographical information system enables the full management of spatially related data and information, which is true for city land evaluation. A general purpose system for city land assessment, named CLAS, was developed with the combination of C and Assembly Language. Two application cases in China prove the functions of CLAS and the effectiveness in land classification and base value determination for large and moderate city.

1. INTRODUCTION

The collection and analysis of information improved greatly in most aspects with the development of computer technology. The development of geographical information system (GIS) enables the full management of spatial data and information. Classification of land class and the evaluation of estate base value has an obvious significance in the regulation of the estate market, the efficient use of land, the reasonable allocation of land resources and the reduction of the national property loss in China (Shuangliu Bureau of Land Management et al 1993). It was found that GIS is a feasible and economical tool as to time, quality, convenience and dynamics (Chengdu bureau of Land Management et al 1992). This paper discusses the design and programming of a city land assessment system (CLAS) and its applications in practices in Chengdu, a big city, and Dongsheng, a moderate town at county level.

2. CONCEPTUALIZATION

An important step in the conceptualization of general CLAS involved the research and selection of the proper data structure and suitable platform, and the development of a method for storing large quantities of data that would satisfy the requirements of a hierarchical system being developed specifically for case studies.
The advantages and the disadvantages of raster and vector data structure seem to complement with each other. This is true concerning programming, analysis, accuracy and output. For raster data structure, programming (Peucker et al 1975, Nagy et al 1978) and land use suitability (Buckner 1977) is much easy. It is typical to complete the overlay analysis with high speed and relative accuracy that interested regional planner, plant site designer and military strategist (Burrough 1986). Effective storage, especially for spatially sparse data (Nagy et al 1978), high accuracy in measurement and area estimate, and direct accesses to most available thematic and administrative maps (Bartolucci 1983) are the main advantage for vector data structure. The plotted maps and vector legend and symbols, like railway, circle, triangle, are precise and illustrative (Burrough 1986). In the actual projects, therefore, both data structures are jointly in use and indispensable.
The suitable platform for software operation should consider the widespread hardware available in China. At big city and provincial institute, there may be high-class computers and high-quality input and output peripherals available or affordable. Most potential users, however, are from moderate city or town at county level and there are only low-level computer platforms, such as microcomputer 386/286 with standard EGA/VGA, small size tablet digitizer/scanner, printer and plotter. Therefore, the basic computer requirements are set at 80386 CPU, 640K RAM, EGA/VGA display, one hard drive, one serial port and one parallel port.
To manage the attribute data for both raster set and vector one, a simple relational data management system is developed. It enables key-entry, data list and querying.

3. DESIGN OF CLAS

With the consideration of the incorporation of raster and vector data and map matching, the final system includes the following modules and the general structure is shown in Fig. 1.

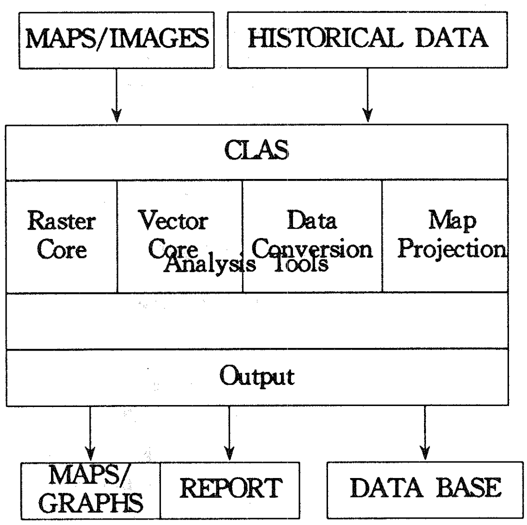

Fig. 1 Components of CLAS

3.1 Core for raster data

This module includes programs for input of data, display and output. The input program supports that certain raster files could be converted into the system-accepted format. The display program support all the raster images displayed on different screens, include EGA/VGA, Number Nine Graphic Board. The system also provided a 3-D data view routine. The output programs include routines to print images by dot-matrix printer, paint-jet and Tektronix 4693DX real colour printer.

3.2 Core for vector data

The input includes programs for digitizing from tablet digitizer, key-entry for attribute data base, and data format conversion to/from general graphics editing packages.
The editing section includes a friendly man-machine interface support the modification of arcs and attributes. The routines for arc intersection and topology building are also supplied, which result in the final vectors with clear relationship of arc-node, polygon-arc, polygon-polygon and polygon-point. The area of each polygon is also calculated and attached to its associated attribute data base using trapezoid integral algorithms.
Vector output section mainly includes routines for plotting maps on diversities of plotters and dot-matrix equipment. A report generator for associated attribute data was programmed, which supports the output of tables according to users' specific requirements.

3.3 Raster-vector conversion

Routines for data converted from vector to raster and from raster to vector are programmed using C computer language. These routines are essential for the analysis of data in both raster and vector format.

3.4 Map projection

The Guess-Craig map projection is adopted for most topographical maps available in China. These include programs to support the conversion between Guess-Craig coordinates and Longitude/Latitude coordinate and the zonal shift of Guess-Craig projection.
The formula used to calculate the ground coordinate of x and y in metres and the convergence gain of the meridian in the projection transferring program is shown in the following (Wu 1986).

$$x = X + ((((H-58)H+61)M/30+(4E+5)Q-H)M/12+1)NTM/2 \quad (1)$$

$$y = D + ((((H-18)H-(58H-14)E+5)M/20+Q-H)M/6+1)NW \quad (2)$$

$$G = (TW(1+M((Q+E)Q/3+M(2-H)/15)))180/P \quad (3)$$

where $X = RBP/180 - UC(32005.78006 + V(133.92133 + 0.70310V))$; $T = \tan(B)$; $C = \cos(B)$; $H = T^2$; $U = TC$; $V = U^2$; $W = (L - L_0)C$; $M = WW$; $E = e^2C^2$; $Q = 1 + E$; $N = R/\sqrt{Q}$; $R = 6367558.49686$; $P = 3.14159265$; e^2 is the second eccentric ratio of ellipsoid; $D = ((L_0+3)/6) \times 10^6 + 5 \times 10^5$, if 6 degree interval zone; $D = ((L_0/3) \times 10^6) + 5 \times 10^5$, if 3 degree interval zone; $D = 0$, without consideration of zone.
B and L are the coordinates in Latitude/Longitude; L_0 is the prime meridian in radius gratitude.

Inverse calculation use the following formula.

$$B_0 = X/R \quad (4)$$

$$B_1 = B_0 + UC(5.051773759 \times 10^{-3} - V(2.9837302 \times 10^{-5} - V \times 2.38189 \times 10^{-7})) \quad (5)$$

$$B = B_1 - ((((45H+90)H+61)M/30-(3-9E)/H-5-E)M/12+1)MTQ/2 \quad (6)$$

$$L = L_0 + ((((24H+28)H+(8H+6)E+5)M/20-2H-Q)M/6+1)N/C \quad (7)$$

where, $U = \sin(B_0)$; $V = U^2$; $T = \tan(B_1)$; $H = T^2$; $C = \cos(B1)$; $E = e^2C^2$; $Q = 1 + E$; $N = (Y - D)/H$; $M = N^2$.
Affine/projection transformation is also important for map matching. The general formula used to calculate the affine transformation coefficients is the following (Zhao 1990).

$$X = AX_0 + BY_0 + C \quad (8)$$

$$Y = DX_0 + EY_0 + F \quad (9)$$

where X_0 and Y_0 are the pre—transformed coordinates; A, B, C, D, E and F are coefficients found out by comparing the control points, which are at least three.
The projection transformation need four control points at least. The equations are the following.

$$X = (AX_0 + BX_0 + C)/(GX_0 + HY_0 + 1) \quad (10)$$

$$Y = (DX_0 + EY_0 + F)/(GX_0 + HY_0 + 1) \quad (11)$$

where A, B, C, D, E, F, G, and H are decided by the control points.
To check out the error occurred in these transformations, a root mean square (RMS) error for n control points is calculated using the following formula.

$$RMS = \sqrt{e_1^2 + e_2^2 + e_3^2 + \ldots + e_n^2} \quad (12)$$

where $e_n^2 = (X_n - X_{n0})^2 + (Y_n - Y_{n0})^2$.

3.5 Analysis tools

Simple spatial analysis programs are set up. There are routines suitable for both raster and vector data set, which include overlay, subset and simple statistics. The overlay routine is used to overlay maps of points, linear targets, and polygons. The subset program is used to retrieve all the points, lines and/or polygons matching user-defined standards and store these to a file. Simple statistic functions, like mean, sum, and deviation, are provided and cross-sectional maps can be drawn.
Attribute checking and buffering are programmed specifically for vector data set. The attribute-check routine ticks out the polygon lines with comparable left and right identity (ID).
The buffering routine will generate a buffered map according to users' definition.
Most of the modules are programmed in C language. Some low level I/O uses assembly language to increase the speed.

4. CASE APPLICATION

The two application cases are slightly different in the methodology adopted due to the difference of city extent.

4.1 Chengdu City

The main objective of the project is to detect the base value of city land up to each estate. Procedure used in the project is the combination of sampling investigation and historical data with the assistance of CLAS. First, find out the weight of factor and element using Delphi method. Secondly, calculate the effect value of each factor and element by "the assessment method of grid coordinate integrated effect value". Next, the determination of land class relies on "the division method on the total effect value frequency" and " the division on the sectional drawing of total effect value". At last, the calculation of estate base value adopts the estimate of differential profit, in combination with the stripping of differential rent and surplus value, based on land class.

During the procedure, the CLAS play an important role at stages of effect value calculation of each factor, land grade classification and final presentation.

4.1.1 Effect value calculation

The determination of effect value use the raster data analysis procedure. Base map is on the scale of 1:15,000. The map was segmented into a 60-by-70 raster image. The total area evaluated is about 21262.5 hectares, which includes the built-up area and the near suburbs. Each cell has an area of 5.0625 hectares, which meets the requirements of the National Regulations.

Digitize all the distribution maps of 28 elements, including those of point, line and polygon. Key in the apposite effect radius and the correction coefficient for road.

The calculation of effect value of each factor includes three stages. First, calculate the effect value for 28 elements respectively. Secondly, calculate the effect value of nine factors from the result of elements. Finally, calculate the grand total effect value by weighted sum.

Different algorithms to calculate the effect value of each element are identical with point, line and polygon respectively. The point element has an effect radius and the effect value attenuates with linear or index correlation to the distance from the point. The line element has an effect zone which best fits the algorithms of buffering. The polygon element has a difference between inside and outside. The inner part of a polygon has a unified effect value. The outer part of a polygon suits the similar algorithms for the point element. Fig. 2 shows a typical algorithm to calculate effect value of point factor in raster data set.

4.1.2 Determination of land class

The assistant tools for the determination of land class and estate base value includes frequency drawing, sectional drawing, and contour of the total effect value.

4.1.3 Output

The computer screen is the essential medium to show the results of city land assessment. Except maps and images, there are 2-D and 3-D histograms resulted from statistical analysis.

4.2 Dongsheng

The determination of estate base value was based on land profit and trade price in the basic unit of land class. The similar methods are used at the corresponding stage of land assessment to Chengdu City. The methods include " the Delphi method" for the estimate of effect value of each basic unit, and "the division on the total effect value frequency" and " the division on the sectional drawing of total effect value" for the determination of land class.

The base map scale is 1:2500. The assessment area of the town is about 924 hectares with a population of about 40,000.

The application of CLAS in the land assessment of Dongsheng mainly focuses on the management of resulted information. The information includes a data base for each estate value and the final assessment map. The final thematic maps in the data base include land unit map, estate base value map, land class map, and land sample point map. The map projection routines for the transformation between Guess-Craig and latitude/longitude provide the basis for the match of maps from different resources. Fig. 3 shows the operational flow and the final system components for Dongsheng.

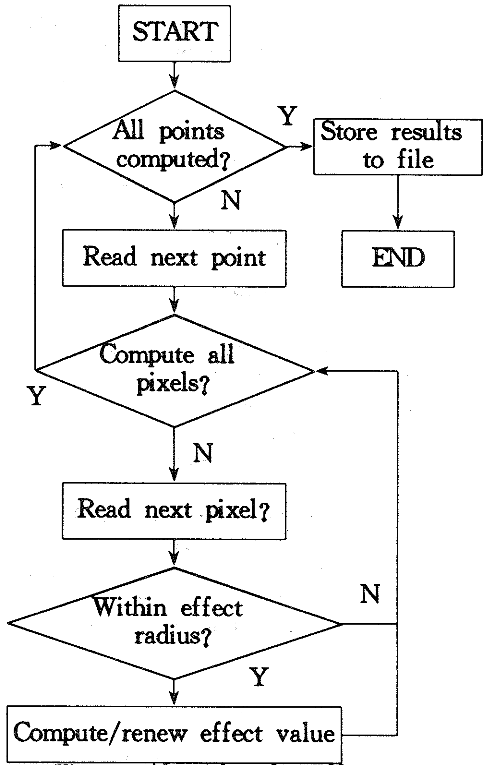

Fig. 2 Algorithm for effect value calculation from point samples

5. FURTHER EXPANSIONS

The increasing demand from the land management departments and organizations prompt the further expansion of the software package to include modules to manage estate and household information and build more sophisticated legend/graphic library.

6. CONCLUSIONS

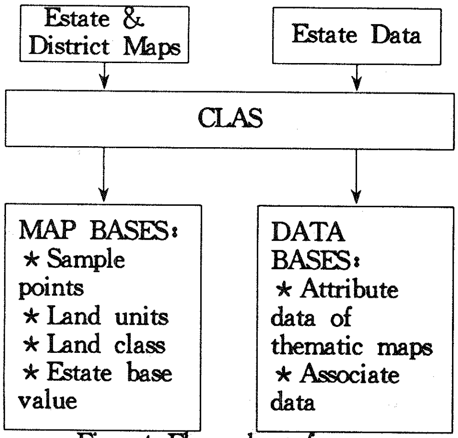

Fig. 4 Flow chart for Dongsheng project with CLAS

It was concluded that GIS was successfully used in the land assessment and has a great potentiality in the forthcoming estate archive management and updating. The achievements derived from the practices at the preliminary stage could be summarized as the following: the design of a GIS fitted for the computer platform in China; the incorporation of raster and vector data structure; the routines for map projection transformation; the preliminary legend data base for mapping; the easy-handling Chinese interface for user; the digitizing routine for the entry of thematic maps.

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