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GIS AND COMPUTER GRAPHICS

Summary. The subjects of this paper is to analyse the relation between GIS (Geographical Information System) and Computer Graphics. There are some algorithms in GIS approach presented.

SYSTEM INFORMACJI GEOGRAFICZNEJ GIS A TECHNIKA KOMPUTEROWA

Streszczenie. Przedmiotem pracy jest analiza relacji pomiędzy systemem informacji o terenie a grafiką komputerową. Przedstawiono przykład algorytmów rozwiązujących komputerowo niektóre problemy GIS.

1. Introduction

The Geographical Information System (GIS) is a special planned for analysing geographical data. The GIS integrates the spatial and the descriptive data into a single system and makes it possible to use operations for spatial analysing. In this connection the GIS can be regarded as the system of hardware, software and methods which helps managing, processing, analysing, modelling, presenting and collecting the spatial data used for solving complex planning and controlling problems.

There are several a bit different names and definitions for GIS in the scientific literature which might be explained by the different professional obligations of the experts. You can find a good overview of the most frequently used definitions at Maguire (1991), from which the Table 1. contains some. The geographical information systems are often called 'service technology', because they ensure opportunity for many branches of science working with spatial data.

Table 1

The different names of GIS

Multipurpose Geographic data System
Multipurpose Input Land Use System
Computerised GIS
System for Handling Natural Resources Inventory Data
Land Resources Information System
Spatial Data Management and Comprehensive Analysis System
Planning Information System
Resource Information System
Natural Resource Management Information System
Spatial Data Handling System
Geographically Referenced Information System
Geo-Information System
Spatial Information System
Environment Information System
AGIS - Automated GIS
Multipurpose Cadastre
Land Information System
AM/FM - Automated Mapping and Facilities Management

2. An overview of GIS history

It is very surprising, but the idea itself to represent the different geographical data level on several groundmap appeared much earlier than the first computer. The ' A-tlas to Accompany the Second Report of the Irish Railway Commissioners' edited in the middle of the XIXth century contained data on the same map about the popula-tion, traffic, geology and topography. Another curiosity is Dr. John Snow's map which can be regarded as an early example of geographical analysis. His map was used to present the mortality of cholera in London 1854, and helped him to determine the neglected district from which the epidemic had broken out.

These two simple examples prove us that the appearance of the demand did not depend on computer science but its develop did. The change in cartographical analysis was influenced by

- the progress of computers, mainly the computer graphics
- the progress of spatial process' theory in economical and political geography, in planning theory etc.
- the higher and higher education of society.

The computer graphics had an effect again on the develop of a new branch of science. Have a look at the most important events in the field of computer graphics and the geographical information systems by ten years.

The vector graphics marked the computer graphics between 1950 and 1960. Simple geometrical algorithms and models were applied. Accordingly the geographical information systems were used mainly to make easier the graphical representation. The first cartographical systems based on digital background developed at this time, and the first experiments with the digital height models were made in this decade too.

The interactive computer graphics became wide-spread between 1960 and 1970. The approximation using algorithms and the presence of the first geometrical programming languages determined this period in computer graphics. On the other hand a significant progress could be noticed in digital image processing and in the applying of digital height models. One of the first geographical information systems named Canada Geographic Information System (CGIS) was created also at this time and still exists. During its develop many theoretical and practical results were published.

The rastergraphics, animation, computer games and the general use of the first standards were remarkable between 1970 and 1980. It became possible to represent spatial objects unambiguously, and to work out algorithms with geometric complexity. The registering was the main result of the geographical information systems in this term. Numerous estate registering systems (Land Information System) were created in the developed countries. The CAD-adding cartography and the digital photogrammetry evolved as well.

During the next term 1980-1990 the cognitive computer graphics, the move of pictures, geometrical data and method banks, further develop of standardisation were significant. GIS-systems appeared which could be used to make more complicated spatial analysis and to help to make decision. Country-wide registering systems were created.

Nowadays both fields are developing harder than ever. The survey made in 1989 shows that there exist approximately 1000 GIS application developing company in the world. (see Table 2.)

Table 2

GIS applications and companies

AGIS	Delta Data System, Inc.
ARC/INFO	ESRI
ATLAS	Strategic Locations Planning, Inc.
Deltamap	Deltasystems
Earth One	C.H. Guernsey & Company
EPPL 7	MN Land Management Information Center
ERDAS	ERDAS, Inc.
FMS/AC	Facility Mapping, Inc.
GeoSQL	Generation 5 Technology
GeoSpread Sheet	Geographic Data Technology, Inc.
Geo Vision	GeoVision Corp.
GFIS	IBM Corporation
IMAGE	US Statistics, Inc.
Informap	Synercom Technology, Inc
Laser-Scan	Laser-Scan Limited
Map Graphix	ComGraphix, Inc.
MapInfo	MapInfo Corp.
SPANS	Tydac Technologies Corp.
System 9	Prime Wild GIS
TIGRIS	Intergraph Corporation

3. Computer graphics in GIS

A geographical information system usually consists of four components: data input, data management, data analysis and data presentation, from which the last two ones are closely connected with computer graphics. Well-known algorithms are brought to light while they change a bit in order to go better to the new systems. Using the GIS-specified attributes the algorithms sometimes become more efficient. It is true that the user of these systems does not meet these algorithms directly, but the reliability and the quickness of the systems depend on them.

During the data analysis you must first select the data then the appropriate analysing operations can be performed. These operations can be chosen from the following ones:

- operation from computed geometry (measuring, counting, computing)
- polygon overlay
- statistical computation
- function for network analysing
- modelling, analysing operation
- other function

Intersection problems and their variations arise in many disciplines, such as architectural design, computer graphics, GIS applications, pattern recognition etc.

3.1. The intersection of two lines

This problem, which seems to be rather simple, plays a very important role in geographical information systems. It is used frequently in polygon overlay operations, merging polygons, lines and the 'point in polygon' operations are based on it as well.

The simplest case is to determine the point of intersection of two line segments specified by their endpoints. The computing consists of two basic steps:

- computing the additional data (steepness, etc.)
- decide whether the point of intersection can be found between the point pairs. During the computations we must play attention of course to the special cases as well (parallelism, verticality, etc.).

In the next case we search for the point of intersection of two lines consisted of n_1, n_2 line segments, respectively. We can compute all the common points by using a cycle which determine the points of intersection of all the line segments belonging to the first and the second line. This procedure requires $0(n_1*n_2)$ time, which can be reduced applying heuristic. We define the minimum enclosing rectangles of a line as the rectangle specified by the greatest and the smallest x- and y-coordinates of the line.

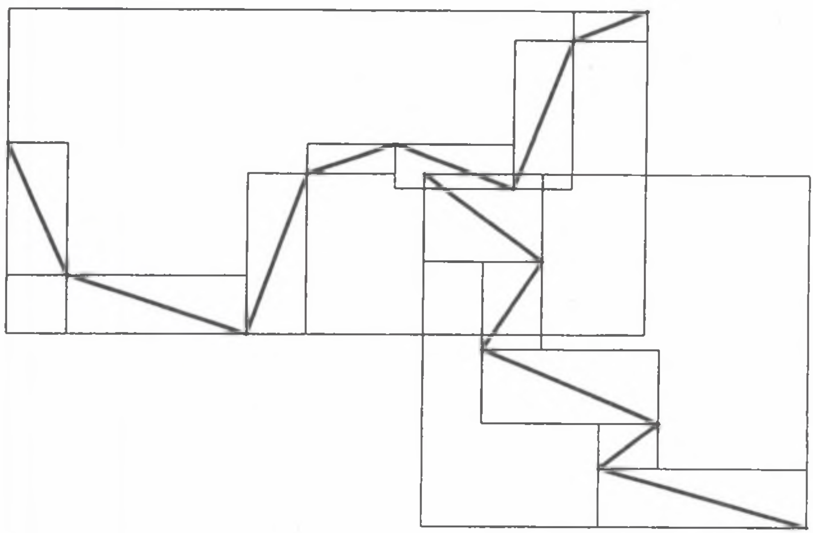

Fig.1. Minimum Enclosing Rectangles

After making these minimum enclosing rectangles if we find them disjunctive, then the two lines do not intersect each other. Otherwise we cannot claim of course they are intersecting, but making the minimum enclosing rectangles for each line segments of both lines we must use the above mentioned algorithm just for line segments which belong to different lines and its minimum enclosing rectangles overlay.

3.2. The 'point in polygon' problem

The basic problem is to determine whether a given point is inside a given polygon or not. This procedure can be applied well when our purpose is to report the polygon among a set of polygons which contains a given point. We would like to know, for example, which county a given object is situated in or the given object belongs to an area possessing a given property.

The basic idea of the algorithm is the following:

- let us draw a vertical line from the given point
- count how many times intersect the line the sides of the polygon

If the number of intersections is odd then the point is inside the polygon, if it is even the point is outside. Instead of using a real counter we apply a variable (n_of_int: number of intersections) whose value can be 1 or - 1 according to the number of intersections is even or not. If the program has found a point of intersection the value of n_of_int changes. Let (u, v) denote the given point and (x_i, y_i) the polygon's vertices, where i = 1,..., n and $(x_{n+1}, y_{n+1}) = (x_n, y_n)$.

```
dir: = 0;
n_of_int: = 1;
for i: = 1 to n do
    if (x_{i+1} <> x_i) then
        if (x_{i+1}-u)* (u-x_i) > = 0 then
            if count (x_i, x_{i+1}, u, dir) then
                begin
                    b: = (y_{i+1} -y_i)/(x_{i+1} - x_i);
                    a: = y_i - b* x_i;
                    v_i: = a + b* u;
                    if v_i then n_of_int: = n_of_int* (-1)
                end
```

We must specify precisely what we mean under intersection in this algorithm:

- if the line specified by (x_i, y_i) and (x_{i+1}, y_{i+1}) are situated in different sides of the line that prove the existence of the intersection

- if (x_i, y_i) or (x_{i+1}, y_{i+1}) is on the vertical line drawn through the given point (critical case) we use the function *count* which tells we must search for the point of intersection or not

The basic idea of this function is that there is a real point of intersection only in case, where x_i and x_{i+2} are in different sides of the vertical line. I use a variable called *dir* (like direction) for the realisation, whose value helps to describe the current situation:

- dir = 0 indicates there was no critical case up to this point or if it was it is solved
- dir > 0 indicates that in the last critical case one of the two points (x_i, y_i) and (x_{i+1}, y_{i+1}) is situated in the left hand side of the line (its x-coordinate is less than u)
- dir < 0 indicates that in the last critical case one of the two points (x_i, y_i) and (x_{i+1}, y_{i+1}) is situated in the right hand side of the line (its x-coordinate is greater than u)

```
function count: boolean;
  begin
      if (x[i+1] - u)* (u -x[i]) = 0
        then if dir <> 0
              then begin
                  count: = false;
                  count: = not ((dir>0) xor (2*u - x[i] - x[i+1] < 0));
                  dir: = 0
              end
            else begin
                  dir: = 2* u - x[i] - x[i+1];
                  count: = false
              end
            else count: = true;
  end;
```

The program goes well in case of isolated islands, polygon containing a hole with an island, and in case of concave polygons as well.

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Recenzent: Prof. dr hab. inż. Stefan Przewłocki

Streszczenie

Treścią pracy jest analiza relacji pomiędzy, systemem informacji o terenie (GIS) a grafiką komputerową. Autorka przedstawia rys historyczny rozwoju GIS i analizuje elementy grafiki komputerowej, znajdującej zastosowanie w tym systemie. Bardziej szczegółowo omawia problem wyznaczania wspólnego punktu dwóch prostych, a następnie zagadnienie przynależności punktu do danego wielokąta. Obydwa zagadnienia odgrywają ważną rolę w systemie geograficznej informacji. Autorka przytacza sposób ich rozwiązania za pomocą konkretnych algorytmów programu komputerowego.

Pracę uzupełniają tablice zestawiające różne nazwy stosowanych systemów informacji o terenie i niektórych, realizujących je, korporacji.