prof. Mykhailo Vasiukhin, Ph.D.
prof. Oleksii Tkachenko, Ph.D.
Iuliia Ivanyk, M.Sc.
National University of Life and Environmental Sciences of Ukraine in Kyiv
Anisa Kasim, Ph.D.
Institute of Cybernetics in Kyiv

Methods and means for building a system of visual images forming in GIS of critical important objects protection

Introduction

Creating a map database (various sizes and scales) and the development of methods for displaying a real-time moving objects of are the main objectives of GIS for protection of critical important objects. Visualization of moving ground, air and space objects on the map background is the goal of the second task. System of forming visual images of the dynamic environment is important to realize these objectives. This system includes an image corresponding electronic maps and the sequence of frames with characters of moving objects (MO).

Analysis of the problem (Korzeniowski L.F., 2012, s. 76) showed that existing methods and tools for the construction of visual images in GIS not developed enough (Лобанчикова Н.М, 2010, с. 24-26). The reasons for this:

- lack of sufficient funding for map updating;
- limited and primitive library of moving objects characters.

The authors reviewed software for building and creating real time map database (RT MDB) software and GIS platform (Васюхин М.И., et al, 2011, с. 341-343.):

- Karta or Map (Panorama, Russian Federation);
- ArcView, (Environmental Systems Research Institute, ESRI, USA);
- MapInfo, (MapInfo Corporation, USA);
- Digitals (Geosystem, Ukraine);
- Oko and Mapa (Ukraine) etc.

ISSN: 1898-4509

Material and methods

RT MDB is a main source for building map background, on which moving objects for remote control on the land, in the air and the space are displaying.

Comparing the different systems, we can note Digitals. That is a ukraininan software, and it can be considerate as a shell for creating RT MDB. Its advantages:

- low price;
- powerful mapping kernel that can be use thousands of raster images and hundreds of thousands of vector objects (signs);
- support of full process chain: from processing aerial and satellite images to print technical documentation;
- reading and writing files in the popular formats;
- not strong requirements and easy to learn.

Stages of cartographic materials (in Digitals):

1. *Aerophotography*. The result of this phase is a set of .jpg files.
2. *Topographic and geodetic work*. Definition of the coordinates of points on the surface of the land.
3. *Processing of aerophotography results*. Ortho- image transformation using stereo-pairs. Stereo films are used to terrain decrypting and for building MDB, describing Relief information layer. Ortho-photo images are geometrically equivalent to maps and demonstrate objects on the land's surface in their true orthographic positions.
4. *Photogrammetry work (rectification)* provides a geo-linking for image of place. Geo-linking is converting photos into a format that is independent of the data sources and procedures used after radiometric and geometric correction.
5. *The integration (collection)* of mapping information:
    - selection of base layers;
    - choice of coordinate system;
    - insertion of triangulation block, ie bitmaps stereopairs;
    - selection of the active layer and template collection;
    - registration turning points of geographic features;
    - semantic description of geospatial objects, their signature and control.
6. *Field decryption* – correction data obtained from the previous phases (Васюхин М.И., 2002, s 111-118).

Data sources for the MDB also may be

- remote sensing data;
- digital maps;
- data from electronic total stations;
- data from satellite navigation systems;
- information from the Internet

Objectives and content determine the specific of the MDB structure for precision farming. This database should have such properties as speed, integrity, flexibility, accessibility and versatility. Priority for modeling and designing MDB is the speed reference to a data warehouse, which depends on the synthesis and logic of relationships between objects and their hierarchy.

The authors proposed a model RT MDB, which solve the following tasks:

- reduce system resources and time for data processing;
- build a model of universal MDB, which can be used not only for the needs of described tasks, but, for example, logistics, industry, agriculture and so on.

MDB is based on hierarchical data model for which the essence of "record", "segment" and "field" are key. Hierarchical object record is set named segments that are interconnected in a tree structure. The segment consists of one or more fields, and has a fixed length and a unique name.

The upper segment is the main, and it contains the object identifier. Properties of the object are detailed at the lower levels of the segment hierarchy. Each segment is associated with only one higher segment; each higher segment has at least one lower. To navigate in the hierarchical model each segment has a unique key field to data access.

The first level is the main segment that contains the ID of defined territory map image. ID determines the type of card, its size and type of mapping projection. Segments of the second level determine target area map partitioning into sheets to components of mini-areas. Each sheet spreads at the third level as a set of segments that represent different layers of description of its mini-area by classes of map objects.

Within each layer there are mapping objects that are defined by the types of components. Some description layers may include set of segments of the fourth level, which are represented by their components. At the fifth level there are segments that describe the spatial characteristics of specific components in each miniarea.

In each such segment there are two types of fields: metric and semantic. The first type represents the coordinates of points, lines or areas that define the spatial characteristics of the described component, the second type is represents an informative description of the component.

Thus, the mapping data model includes:

- content, graphic and spatial part;
- own characteristics: type of projection, scales, etc.;
- set of mapping links between thematic, spatial and graphical data;
- attribute ща mapping relationships;
- iets of integral characteristics of mapping relations and their attributes;
- reflection that defines the characteristics of the model;
- reflection that defines the relationship between the mapping links, their attributes and a set of integrated characteristics;
- reflection that defines the relationship between the classes of objects that are present in the mapping links.

In the proposed model the original map image is divided into map plates as rectangles. The plates are spatial part of the model.

Layering principle is a fundamental principle of thematic organizing of spatial information. Its essence in the fact that various information about a territory is structured as a series of thematic layers. Each layer contains thematic information. Map theme determines content, titles and layer's content, corresponding to geospatial objects. List of layers and the corresponding list of geospatial objects are related to thematic part.

Parameters of geospatial objects that fill cartographic layers, are part of space-themed area, because each object has spatial part (has geographic coordinates), and the content part (linked to the thematic layer).

Library of symbols contains information about how to display geospatial objects as point, line and polygon primitives. It is a graphic part of a model.

Map background is synthesized on the basis of the models. The dynamic component of the system of visualization contains the following blocks (Kasim A.M, 2013, c. 128):

- module for preparing and creating presentation ways of complex characters with extended attributes for the three types of moving objects (ground, air and space);
- module for creating character transparency on a map background;
- module for flipping representation of moving characters.

In the first module preparing of symbols with extended attributes implemented at the program level and it is based on the method of designing characters of moving objects for radar monitoring (airplanes). Based on input data received from radar (height and speed, length and wingspan, engine type), type of airplane character select from set of given super types (nose, wings, tail, engine) and its location in the character image.

According to that approach there is proposal to design the character with the extended attributes using known function of quasi-optical image plane (Козак Ю.А., et al, 2000, C.123-126):

$$S(x,y)=\sum_{i=1}^{N} S_i(x,y)P_i(x,y), \quad (1)$$

where $i=\overline{1,N}$ – number of elements of character; $S_i(x,y)$ – image of i-th element of character; $P_i(x,y)$ – function for location of *i*-th element of character ($S_i(x,y)$).

For other types of moving objects symbols are standard (view from top to down). This approach is based on the algorithm (Каркищенко А.М., et al, 1998, C.107-111). This allows to trace the contour of an image and create an array of control points. The points are connected by graphical primitives that form character. This is considered a discrete binary image *I* on background *F*, and $I = K \cup I_0$, where *K* – the contour of the image, I_0 - the inner area of the image, which may also contain other paths. Image *I* is flattened and not contain hanging points.

Description of image *I* is given by dot (point) matrix

$$\left(a_{ij}\right)_{i=1,j=1}^{i_{\max},j_{\max}}, \quad a_{ij}=\begin{cases}1,(i,j)\in I\\ 0,(i,j)\notin I\end{cases}. \quad (2)$$

The algorithm uses the following parameters: *h* – initial limit of checkpoints selection (*h*≥0); Δ*h* – change of checkpoints selection limit (Δ*h* > 0); *r* – neighbourhood size of checkpoint (*r* > 0). To calculate the distance between the elements *I* on background *F* it is necessary to introduce some metric $\rho(s,k)$ on the discrete plane. As such metrics can be selected: uniform $\rho(s,k)=\max\{|s|,|k|\}$, Euclidean $\rho(s,k)=\sqrt{s^2+k^2}$, Hamming $\rho(s,k)=|s|+|k|$ or others.

The following steps of the algorithm of checkpoints selection and construct a vector representation of the image of a moving object.

1. Analyze the elements of dot matrix $\left(a_{ij}\right)$ left-to-right, up-down, and find the first element $a_{i_0 j_0} \neq 0$. Let $n := 0$, where n – number of tracked contour point.

2. Find the starting points circuit around the last contour point of the path tracked $M(i_0, j_0 - 1)$.

3. Consider r – neighbourhood of point (i_n, j_n) $U_r^{(n)} := \{(s,k): \rho(s-i_n, k-j_n) \le r\}$. Count the number of matrix elements a_{ij}, $(i,j)\in U_r^{(n)}$,

which belong to the background $F: P_n = \sum_{(i,j)\in U_r^{(n)}} a_{ij}$, and not belong to it: $\overline{P}_n = \left|U_r^{(n)}\right| - P_n$, where $\left|U_r^{(n)}\right|$ – power (number of points) from neighbourhood $U_r^{(n)}$.

4. Calculate the weight v_n n-th point: $v_n = \frac{P_n - \overline{P}_n}{\max\{P_n - \overline{P}_n\}}$ (Каркищенко А.М., et al, 1998, C.107-111).

5. If $|v_n| \geq h$ then (i_n, j_n) is checkpoint, and add i_n into vector $X_h = (i_0, i_1, ...)$, j_n – into vector $Y_h = (j_0, j_1, ...)$, v_n – into vector $V_h = (v_0, v_1, ...)$.

6. Continue circuit of contour. Let $M_0, M_1, ..., M_7$ are matrix's elements (a_{ij}) that located around element $a_{i_n j_n}$ clockwise, moreover, $M_0 := M$. Find first nonzero matrix element of the surrounding elements $M_0, M_1, ..., M_7$. If M_k is it then $n := n + 1$ and $M := M_{k-1}$.

M_1	M_2	M_3
M_0	$a_{i_n j_n}$	M_4
M_7	M_6	M_5

7. If $a_{i_n j_n} = a_{i_0 j_0}$ then image contour circuit is finished, and we must go to step 8< else – go to step 3.

8. Let m – size of vector X_h (number of control points). If $m < M_{\min}$, namely number of checkpoints is not large, then $h := h - \Delta h$, and we must got to the step1 (to do new contour circuit). If $m \geq M_{\min}$ then array of checkpoints is built.

After the algorithm of research contour and identify checkpoints, we have three vectors: $X_h = (i_0, i_1, ..., i_m)$, $Y_h = (j_0, j_1, ..., j_m)$, $V_h = (v_0, v_1, ..., v_m)$ – abscissa, ordinate and weight of checkpoints. Three (X_h, Y_h, V_h) is the skeleton of image I. Obviously, in the checkpoints edge of image is most significant breaks. That is why polygon I_m, which is obtained by the serial connection of control points, is an approximation of the original image. And the greater the number of control points, the more accurate approximation (Каркищенко А.М., et al, 1998, C.107-111).

Character images, which prepared by described approach, build by method of base point of a vector character. Another way to prepare characters moving objects is previous storing images in databases of characters (Касим A.M, 2013, s 99-112.).

Depending on the complexity and richness of character elements, such databases contain:

1. Raster or vector image of character for each moving object. Other derivative images of character can get using sine-cosine transformation.
2. All character images, which returned to a specific angular step.
3. Base images of character. Derivative images should be generated by a method of base azimuth-oriented character bitmap images. For getting a derivative image, this method requires to change a memory reading mode for base image. Using the symmetry of the main directions of the character's orientation and discrete rotation angles leads to a decrease in the number of prepared images.

The second module provide priority for output characters of moving object relation mapping background by using transparent masks.

The third block is designed to realistic and smooth displaying of linear-rotary moving of characters that presented as sequences of sprites (Касим A.M, 2013, s 99-119). Functional modules of visual images forming system obtain data on the current coordinates of moving objects from satellite navigation systems and/or radar.

For normal conditions, GPS-receiver that mounted on mobile agricultural machinery or air objects pass own coordinates to the software module with a period of one second, that measurement takes place every second. You can achieve the update frequency of coordinates of a moving object, to use radar network.

For continuous measurements there is describing of path (route) of moving. All points of the track (angular coordinates: latitude and longitude) is automatically written into a route file.

Conclusion

The paper proposes methods and tools for the construction of the system for forming visual images in GIS of critical important objects protection. The system include model of map data, which is the basis for a RT MDB, and methods of improved visualization of dynamic scenes to show the movement of moving objects.

References

Korzeniowski L.F. (2012): *Podstawy nauk o bezpieczeństwie*, Warszawa, Difin

Černoch F., Kister Ł., Ocelík P., Osička J., Smyrgała D., Zapletalová V. (2012): *Shale Gas in Poland and the Czech Republic: Regulation, Infrastructure and Perspectives of Cooperation*, Brno, Masaryk University in Brno, International Institute of Political Science

Лобанчикова Н.М. *Моделі та методи побудови автоматизованої системи виявлення та попередження надзвичайних ситуацій на території аеропорту*: 05.13.06

Васюхін М.І., Гулевець В.Д., Іваник Ю.Ю., Долинний В.В., Корнiюк Б.А., Савчук В.В. (2011): *Імітаційна модель повітряної обстановки над територією аеропорту та прилеглих до нього зон,* Вестник Херсонского национального технического университета, № 2 (41)

Васюхин М.И. (2002): *Алгоритмические и программно-аппаратные методы и средства построения интерактивных геоинформационных комплексов оперативного взаимодействия*: дис. … докт. техн. наук: 05.13.1

Касім А.М. (2013): *Методи та засоби формування динамічних сценаріїв в навігаційно-керувальних комплексах*, автореф. дис. канд. техн. Наук, 05.13.06/Нац. акад. наук України, Ін-т кібернетики ім. В. М. Глушкова

Козак Ю.А., Куприянов А.Б., Данилюк И.А. (2000): *Синтез квазиоптических изображений самолетов по данным радиолокационных средств*, Труды Одесского политехнического университета, №3(12)

Каркищенко А.Н., Лепский А.Е., Безуглов А.В. (1998): *Об одном способе векторного и аналитического представления контура изображения*, Интеллектуальные САПР: Всерос. науч.-техн. конф.: материалы, №2(8)

* * *

Artykuł uzyskał pozytywne opinie wydane przez dwóch niezależnych Recenzentów.

Mykhailo Vasiukhin
Oleksii Tkachenko
Anisa Kasim
Iuliia Ivanyk

Methods and means for building a system of visual images forming in gis of critical important objects protection

Abstract

Requirements for the visualization of dynamic scenes in security systems for are increasing in recent years. This requires develop a methods and tools for visualization of dynamic scenes for monitoring and managing the system of security like "human--operator". The paper presents a model map data from which is a base for building real time map data, and methods of real time visualization of moving characters in air.

Key words: system of security, real time map database, map background, dynamic visual image, GIS, visualization of moving objects.

Резюме

Требования к визуализации динамичных сцен в системах безопасности в последние годы растут. Это требует разработки методов и средств визуализации динамических сцен для мониторинга и управления системой безопасности со стороны оператора-человека. В работе предложена модель картографических данных, на основе которой строится база картографических данных реального времени, методы и средства движущихся символов движущегося в околоземном пространстве.

Ключевые слова: *системы безопасности, картографические базы данных реального времени, картографический фон, динамический визуальный образ, ГИС, визуализации движущихся объектов*