Information Modelling through GIS for Visualizing Air Alarms

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Abstract

In this project, an information system for the visualization of geographic data was developed, which displayed information on a map of Ukraine regional air alarms. Two data models in geo-information system (GIS), namely vector and raster, were investigated. The methods of data interpolation with raster and vector GIS data are described, and the conditions of their application are defined. On the basis of this research, an information system for the visualization of geographic data was developed, which displayed information on a map of Ukraine regional air alarms. The project was implemented as a website where you can check which place or area an alarm is currently sounding. Further you can track when and where there were previous air alarms making it possible to analyze information about the frequency of alarms for each area.

Keywords[1]

Geo-information system, GIS, vector model, raster model, air alarm, air raid, geo-visualisation

1. Introduction

Nowadays, it is important to be able to quickly and easily obtain information about the situation in the world, which is constantly changing. Software technologies have an increasing impact on all aspects of our lives: the study of intelligent systems and cloud technologies that provide online services [1-2], the development of the Internet of Things, which would be influenced by "smart" devices in all aspects of our lives [3], application of intelligent decision support systems and their mathematical modeling [4-5]. Very often, this information is related to factors that we cannot point to, but only accept as a fact. However, modern information technologies do not allow us to research, analyze and visualize these data [6], which can be used for the benefit of people in the future. An example is weather changes. If we did not know where it was going to rain, many people would get drenched and complain that the meteorologist are always wrong. However, there are synoptic maps that remind us to bring an umbrella with us from the morning. In general, this type of information is called geo-visualisation.

Geo-visualisation, also known as cartographic visualisation, is a tool and technique that support and help analyse geospatial data through interactive means. This research method presents geospatial information in a way that, when combined with human understanding, allows data to be explored and correct decisions to be made. This information technology combined with a standard map provides us with real-time information, allowing users to adjust the displayed data on the fly and stay up-to-date.

Today, there are many different applications that provide us with these capabilities. One of the best known is Google maps, which is used by more than a billion users every month. With this service, you can analyse traffic in real time, plot the routes of any mode of transport and even pedestrians. It allows getting information about various establishments in the city and traffic jams, view satellite images of the area and much more. Google maps therefore is a very ambitious and important aspect for both global and individual decision making. Therefore, geo-visualisation has become an integral part of our lives, although we do not even think about it. This project developed a geo-visualisation information system that displays air raid alert information in Ukrainian territory on a map based on an open-source world map with the addition of air-raid information. Presently this problem is very real for Ukrainian citizens

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because it directly related to their personal safety and life. These factors demonstrate the relevance and importance of this project.

The project was implemented as a website where one can check which city or region currently has an air alert, track where and when there has been an air alert before, giving individuals an opportunity to analyse where air alerts and air raids occur more often and where they occur less frequently.

2. Relevance of the topic

This project is currently timely because it is closely related to our own lives and safety. Air raid alarms are happening every day in different parts of our country, so we always need to know exactly where it is happening. Also, this information provides an opportunity to analyze where current air raids and potential air raids may occur. This project is timely because it is closely related to our own lives and security. Air raid alerts happen every day in different parts of our country, so we always need to know exactly where they are happening. In addition, this information provides an opportunity to analyze where current and potential airstrikes may occur. Our air raid warning map is more detailed and displays information not in an abstract form, like known applications, but on a real map of Ukraine. The map shows not only the borders of the areas where the aviation alert was announced, but also the borders of the cities Figure 1. The borders of the air raid site, as well as the borders of the city, because it often happens that the siren is not triggered in the entire region, but only in border cities with danger zone. A map of the image of information in a similar system is presented in Figure 2.

Figure 1: The appearance of our map

Figure 2: Map appearance of a similar project

3. Problem statement and technology research

The primary task of our project was to create an interactive web-site using the information web-server that would display on a map of Ukraine information about the air-raid in a certain city or region. With the use of web-server, which stores all information about the air danger.

To create the hardware part of the project we used the following core technologies: ReactJs, JavaScript, Node.js, CSS, an open world map using Leaflet library, a web server with information about the air danger. Since the information system is a website, so it was appropriate to use modern developments that are currently popular in the web technology market. The backbone of the project was JavaScript and its framework, React, which is by far the most popular among developers worldwide.

The most important part of our project is information about the dangers of air raids. We took this information from an open web server where all the information we need, such as coordinates, location, time and more, is stored. This method is quite convenient because we do not need to use a database to store all this huge amount of information which is updated every day, we just make a simple query to the server. This greatly improves the performance of the program and reduces the complexity of coding. However, problems can arise if the server stops working, then we won't be able to use our system.

The main challenge of our project was not only to develop the information system but also to use all the technologies we had chosen correctly and productively. Another important factor was the ease of use of the software. It is often the case that a programmer works flawlessly, but it is difficult for the user to understand it through a complex interface, so the user will use less functional but more comprehensible analogues.

4. Information organization and processing in GIS

The term geographic information systems represents the integration of many subject areas. To date, there are a large number of definitions of the term "geographic information systems". Some of them differ from each other, as they each interpret GIS from their own point of view. Let's consider a few of them:

"Geo-information systems are tools for processing spatial information, usually clearly tied to some part of the earth's surface and used to manage it." [7]

"GIS is a real-world application that includes hardware, data, software, and people needed to solve problems [8].

"GIS is a system of hardware, software and procedures that facilitates the management, manipulation, analysis, modeling, presentation and display of georeferenced data to solve complex problems of planning and resource management" [9].

GIS is a bank of spatially bound data that describe geographic objects (coordinates of location on the Earth's surface; qualitative or quantitative characteristics). The use of GIS makes it possible to increase the efficiency and quality of work with spatial information in comparison with traditional mapping methods. Simply put, GIS are created to automate the processing of spatial information using modern computer methods. In the technological aspect, GIS appears as a means of collecting, storing, transforming, displaying and distributing spatially coordinated geographic information. And finally, from the production point of view, GIS is a complex of hardware devices and software products designed to ensure management and decision-making, and the most important element of this complex is automatic mapping systems. The essence of geomodelation consists in the submission of objects and relations between them, proceeding from the principle of unity of place and time. Geo-information modeling allows to organize all known geo-objects and phenomena relative to space and time. Geomodelation model can be represented in the form of a cortege:

$$F, ft ,Rr,Shi,Aik ,Sik ,Pm,Ci ,Wi, auxiliary\_data,$$

where F – purpose (or task setting) of geomodelation;

ft – local tasks – components of the general task of modeling;

Rr – the relations between objects on the map;

Shi – shape with landscape objects (corresponding to local task ft);

Aik – attribute table of the k-th object of the i-th shapes;

Sik – measurement scale for attributes of corresponding data sets;

Pm – processes that require modeling;

Ci – criteria for optimal decision-making;

Wi – i data set scale.

Any GIS own advanced means of input data processing and analysis in further order to their realization in the real form. Figure 3 represents the scheme of information processing in GIS.

Many GIS software packages have data interpolation modules, mostly intended for creating continuous surfaces. These surfaces represent the terrain, the bottom of the lake, the temperature or distribution of the chemical component [10-12]. Extrapolation is a procedure for predicting the attribute value outside the area wracked by measurements, but with using some statistical correlation functions as the result of interpolation. This is most often done by creating a statistical correlation between two parameters within a certain area and using it in a new area or in extent. The simplest example of interpolation that linear interpolation between two points. Other methods of interpolation include:

- polynomial functions;
- splines;
- kriging;
- moving average;
- fourier functions.

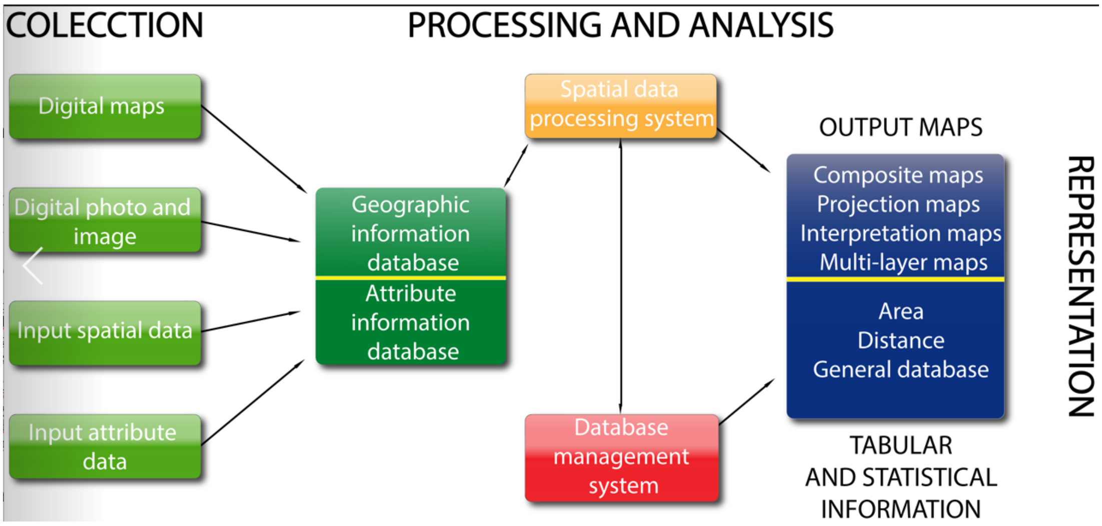

Figure 3: the scheme of information processing in GIS

Each of them has a certain statistical mathematical mechanism [13], which is applied to the data. It is assumed that these mathematical functions correspond exactly to the physical state of data distribution. Since the most common procedure during the interpolation is measuring distances between data points, calculating is easier and faster if the data is organized in a grid, lattice or matrix.

4.1. Interpolation with raster and vector GIS data

In the case of vector data, there are the most common methods: Thiessen Voronoi polygons method and triangulated irregular network (TIN) method, rational function method.

The Thiessen-Voronoi Polygons (nearest neighbor method) (Thiessen Voronoi polygons) [14-15]. As an evaluation of the variable in some point of the investigated area takes the value, which has the nearest (according to the Euclidean distance) sampling point. This method is recommended for using if the initial sample points are located in the space regularly or almost regularly. The evaluation of the investigated function at the point is determined by the formula: $Z_0 = Z_i$, where *Zi* is the value in the sample point, which is located closer to others to the location (X0,Y0). Due to the fact that on the polygon is only one point of measurement or observation, there is no possibility to assess the internal variability of the variable.

4.2. Rational function method

The essence of the method consists in representation of the interpolated function (a number of table values) in the ratio form of two polynomials. The interpolation by rationals functions consist in representation of the function of interpolator *f(x)* in the ratio form of two polynomials:

$$R(x) = \frac{a_0 + a_1 x + \ldots + a_p x^p}{b_0 + b_1 x + \ldots + b_q x^q}, p + q + 1 = n. \quad (1)$$

Coefficients a_i and b_i are defined from a set of relations $R(x_j) = f(x_j), where\ j = 1, \ldots, n$, which are written in the form:

$$\sum_{j=1}^{p} a_j x_i^j - f(x_i) \sum_{j=0}^{q} b_j x_i^j = 0. \quad (2)$$

4.3. Triangulated Irregular Network

Is created a surface which consist of triangles formed by the nearest points [16]. For this purpose around data collection points are helding circles and their crossings are connected to the compact triangles network, which adjoin each other without crossings and gaps (triangulation Delone). Let the point that is interpolated get into the triangle that is formed by points with coordinates (X_1,Y_1), (X_2,Y_2).,(X_3,Y_3). Then in the tridimensional (X,Y,Z) space constructed a plane, which passes through points with coordinates $(X_1,Y_1 Z_1)$, $(X_2,Y_2 Z_2$.,$(X_3,Y_3 Z_3)$.

Plane equation: $aX + bY + cZ + d = 0$, where coefficients can be calculated according to the formulas:

$$a = Y_1(Z_2 - Z_3) + Y_2(Z_3 - Z_1) + Y_3(Z_1 - Z_2); \quad (3)$$

$$b = Z_1(X_2 - X_3) + Z_2(X_3 - X_1) + Z_3(X_1 - X_2); \quad (4)$$

$$c = X_1(Y_2 - Y_3) + X_2(Y_3 - Y_1) + X_3(Y_1 - Y_2); \quad (5)$$

$$d = X_1(Y_2 Z_3 - Y_3 Z_2) + X_2(Y_3 Z_1 - Y_1 Z_3) + X_3(Y_1 Z_2 - Y_2 Z_1). \quad (6)$$

An estimate of the variable Z at the point (X_0,Y_0) will be the corresponding value on this plane:

$$Z_0 = \frac{-aX_0 - bY_0 - d}{c}. \quad (7)$$

The distinctive feature and advantage of such model is that it no transformations of the output data. On the one hand, it does not allow such models to be used for detailed analysis, but on the other hand, the researcher always knows that there are no errors in this model. It is also important that this is the fastest method of interpolation. The main drawback of the method is that the final surface does not look smooth. This is caused by the fact that the received gradients are of an intermittent character, that is, they have drops in the places of joining the elements of triangles. In addition, triangulation works only between data collection points, but not around, and the irregularity of points leads to unexpected results.

Raster data interpolation. There are many methods of raster data interpolation in GIS, including the method of the inverse distance weighted, splines, surface trend analysis, kriging and artificial neural networks. The two most common methods of raster data are: inverse distance weighted and splines.

4.4. Inverse Distance Weighted

Interpolation method of inverse distance weighted consists in the fact that the points are weighted so that the effect of a known point value is quenched with increasing the distance to an unknown point that value must be determined [17]. The evaluation of the investigated function at the point is determined by the formula:

$$Z_0 = \frac{\sum_{i=1}^{n} w_{i0} \cdot Z_i}{\sum_{i=1}^{n} w_{i0}}, \quad (8)$$

$$w_{i0} = \frac{1}{\left(\sqrt{d_{i0}^2 + \delta^2}\right)^{\beta}}, \quad (9)$$

where Z_0 – the weighted value of the variable in the sampled points;

w_{i0} – weight of the sampled points;

d_{i0} – the distance between point where was calculated the evaluation and the i-th point of measurement;

δ – smoothing parameter;

β – the degree parameter that determines how quickly the weight will decrease with the increasing of distance.

Inverse Distance Weighted is flexible and small wide from the point of view of computing resources. The result quality may decrease if the distribution of data collection points is uneven. In addition, the maximum and minimum values of the interpolated surface can be recorded only at the data collection points. This often leads to the so-called "ox eyes" – areas of elevated or underestimated oval shape values.

4.5. B-spline interpolation

Interpolation interval is divided into small segments, each of which is set by the polynomial of a certain degree [18]. Polynom coefficients are chosen in such a way that certain conditions are fulfilled (which are depends on the way of interpolation). Common requirements for all types of third-order splines are continuity of the function and passing through the points offered to it. Each coordinate of the B-spline point (x, y) is described by an equation:

$$P(t) = \sum_{k=0}^{L} P_k \, N_{k,m}(t), \quad (10)$$

where *(L+1)* – control points number;

$(P_k = (x_{k,} y_{k,})$ – control points coordinates;

$N_{k;m}(t); \in 0, \dots, t_{max}$ (t_{max}– the maximum value in the nodal vector *t*, equal $L - m + 2$, where m – the order of the polynomial).

Simplicity in calculation and numerically stable. Sufficient smoothness and support in a small area of the passage. Interpolation of certain control points. B-spline curve interpolates the first and last point, while it approaches to other points. The main drawback of the splines is that at each interval the function is approaches by separate polynomial, also B-spline interpolation poorly corresponds to real physical processes.

5. Overview spatial data displaying methods in GIS

In our research, we worked on the development of geo-information system and investigated the methods that were used for their creation [19-20]. Let's begin with the fact that GIS is a computing system used for recording, saving, modifying, analyzing and displaying geographic information. In short, the main task of the GIS is to process the data, which are divided into spatiality and attributive.

Spatial data refers to such type of information that describe characteristics of objects which occupy a certain territory. There are two main methods to display such data on a map, namely raster and vector. An attributive type of information is required to describe certain characteristics of a spatial object. If with attribute data type everything is clear, then with spatial not everything so obvious, that`s why we decided to investigate the peculiarities of their displaying on the map.

Spatial information about geographic objects is displayed on the map with using sets of basic graphical elements like a points, lines, and areas. Points we use to mark on the map elements physical dimensions of which can be neglected, for example, people, pillars of the street lighting system, telephone towers and so on. With lines we mark on the map narrow spatial objects, whose volume on a scale is not important to us, for example, roads, small rivers, borders of countries. Geographic objects that have shape, location, and area, such as houses and quarters, we marked on the map as areas. Of course, it would be problematic to mark all these objects on the map, and in the future it would not be clear to the end user but even to the developers, so mathematic, as always, comes to help.

For displaying geometric shapes on a two dimensional areas we using basic graphic elements that's used in the vector method of information submission [21]. Typically, these are linear, polygon, and point objects that are constructed on a plane by vectors that`s are designated by coordinate pairs of "X-s" and "Y-s" in digital form. In practice these are geographic coordinates on the sphere, i.e. latitude and longitude, or Cartesian coordinates, obtained in a certain cartographic projection. Of course, there are many of these objects on the plane, so there are assigned their own number Figure 4.

However, the submission of information by simple vector method is ineffective, for example, because the sides of the two adjacent polygons are stored twice. This becomes inappropriate, both in terms of computer memory filling and marking data on the map. Therefore, it was decided to use graphs, Figure 5.

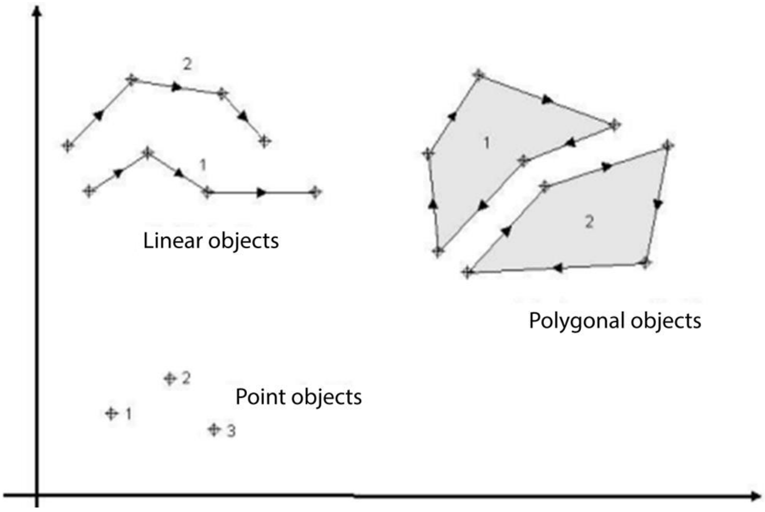

Figure 4: Vector models presentation of objects polygons:

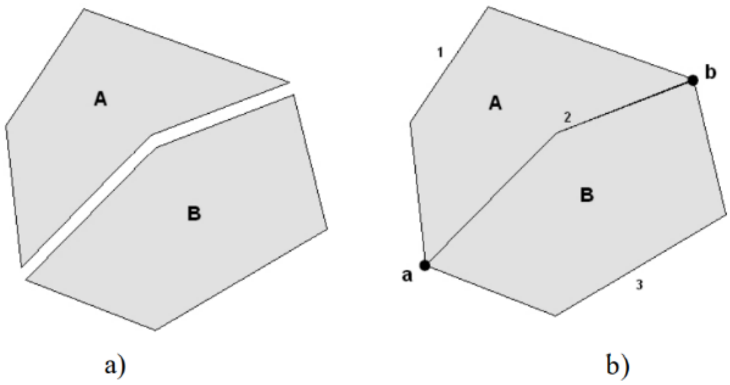

Figure 5: Vector representation of adjacent geographic a) simple b) based on the graph structure

In the first case, the polygons are described by a simple closed sequence of vectors represented by a list of coordinates. The second method describes the polygon using the mathematical hardware of graphs and using the set of arcs (1,2,3) and nodes (a,b). Arc 1 and 2 are defines Polygon A, arcs 2 and 3 are defines Polygon B. Comes out that the limit of adjacent polygons is represented by one arc and is used only once. Thus vector models are used for modeling objects with exact definition of forms and boundaries. Collect data for such models expedient from, for example, digitized paper maps, by means of vectorization of raster data and from topographic surveys. Therefore, vector data is the best way to outline the shape and position of spatial objects. However, they are not quite suitable for continuous phenomena, or spatial objects with inaccurate borders.

We have found that vector models are not suitable for describing continuous space, therefore raster data models are used for this purpose. In this data type the discretization of real terrestrial space is carried out by dividing it into a set of adjacent elementary objects – spatial placeholders. Spatial placeholders is the smallest piece of information in this model, which has one characteristic, or one value that gives to us understanding of what is located in that particular place. Therefore, vector models are used to find out where the object is located, but raster models give us the information what exactly located in this place. The sources of such data are photographic images, drawings, drawings and texts that are converted into digital form through scanning.

In the raster data model, point objects are marked as separate spatial placeholders, linear – a chain of interconnected spatial placeholders, and the regions with a set of adjacent spatial placeholders, which are a two-dimensionals structures. Raster data model of the real terrestrial space represented not just only separate geographic objects, as in the case of vector model, but also that part of space, which remains empty. These continuous surfaces are represented by X, Y, Z coordinates. If X and Y, as usual in this case - is simply coordinates of the spatial placeholders, then Z can representade not only for the height of relief, but for any other values, such as atmospheric pressure, population density, temperature and so on. All raster models [22] in general form are represented by a matrix of spatial placeholders. They consist of rows and columns. The position of each spatial placeholders is indicated by the number C of the column (Column) and the number R of the row (Row) from the beginning of the counting. The starting point of the counting is taken from, either the upper left corner or the lower left corner of the matrix. Each spatial placeholders has a width dx (size in the X-axis) and height dy (size in the Y-axis) Figure 6. Raster data models have many different characteristics, such as resolution, value, orientation, location, and more. We have considered several of them.

Resolution refers to the parameter that is responsible for how accurately the object is pictured. In cases where acurate detalization is important uses a higher resolution, for example for land that will be used for construction a low-rise building, the resolution of the map will be 10 per 10 meters, and for lands of governance of Tenure of Land it will be 5 per 5 kilometers.

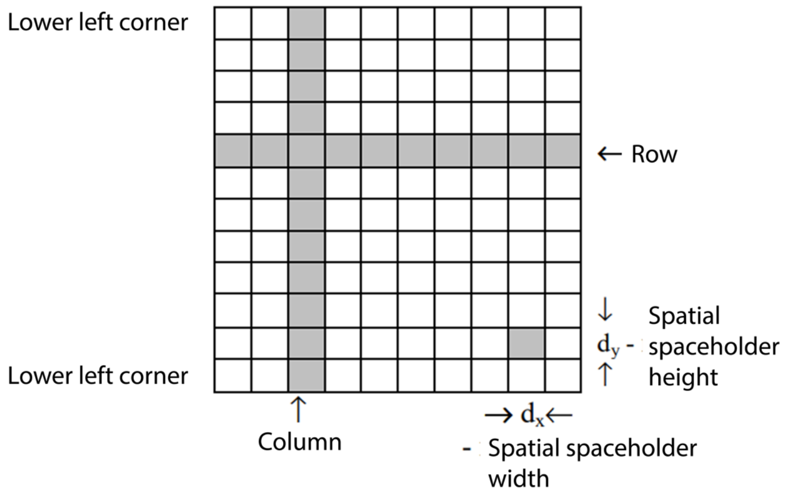

Figure 6: Raster model formation

Each raster has a rectangular shape, all spatial placeholders also have a rectangular shape and dimensions: *dx* - width and height - *dy*. It is formed by spatial placeholders of n lines and m columns Figure 7. The total number of spatial placeholders of the raster will be *n*m*.

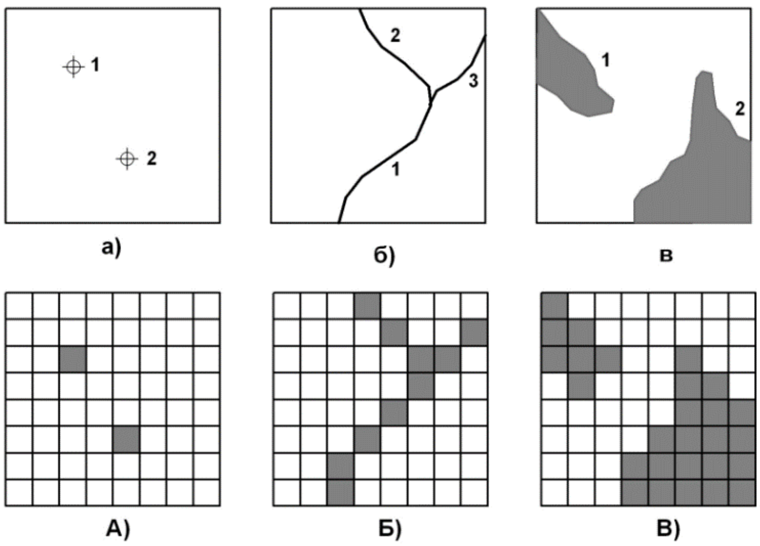

Figure 7: Presentation of geographic objects by raster models: a – point objects; b – linear objects; c – polygon objects (regions)

Each spatial spaceholders is described by three parameters: column number, row number and value Figure 8. These parameters constitute a position and substantial part. The positional part is represented by the line coordinate and column coordinate. The substantial part is represented by the semantic code - a value, with which can be connected an unlimited set of attributes. The value is an element of information stored in spatial placeholders of raster. As a rule, each spatial placeholders should have only one value.

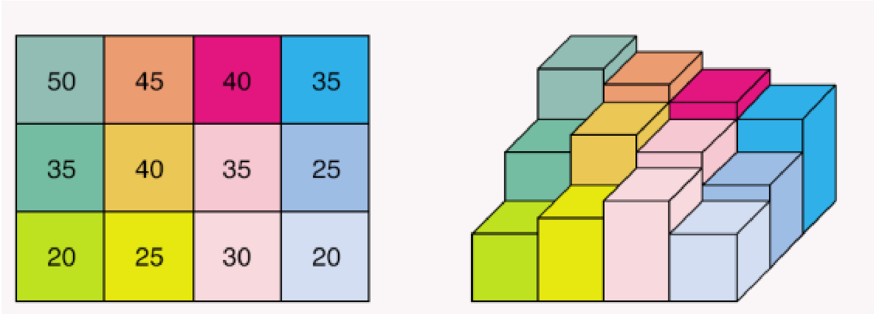

Figure 8: Example of spatial spaceholders values

Thus, the raster model focuses on data oriented on modeling continuous phenomena and images of the ground surface. We can collect this data from satellite images, scans of photos and drawings. The model allows us to analyze spatial data, proximity analysis, surface analysis, dispersion analysis and ways of the lowest costs. Raster data is better for representation of continuous phenomena with gradual variation of attributes, but it is not suitable for representation of point and linear spatial objects.

Raster data models have their own disadvantages and advantages, the disadvantages are that the structure is not adapted to changes of surface relief, gaps of continuity are poorly transferred, precise location of the object is also not transferred well. The advantage is that this model should be used in tasks where the location of objects is not significant.

Compared to vector data models, raster models have the following disadvantages. Geographic objects are characterized by less accurate information about location and sizing, rasters require large memory capacities. However, the advantages are that the model reflects continuous covered areas, data is easier to process and it have higher performance, inputting such data takes much less time and cost.

In our project it was expedient to use vector model of data submission on the basic map because we needed only to mark on it borders of regions and cities that is already known, without any additional information.

6. Development of an information system for visualizing air alarms

The information system of geographic visualization of air alarms is a distributed information system [21-22] presented in Figure 9. In the simplest variant of GIS it consists of client and server. The client sends HTTP requests to the server and receives responses from the server. Depending on the request, the server may send a response to the client in different formats. GIS built on the basis of three-level architecture, which provides for the presence of such levels as: client application, application server, database server. The main difference between the architecture of the GIS of air alarms from the usual web application is the presence in its composition of an additional component, which can be called a GIS server. Often in real applications the role of such GIS-server is performed by several software products. Some publications serve for publication of vector and raster services, others for metadata services, and the third provide the possibility of creating cache file. From the beginning, needed to install the Yarn package manager. It helped us to facilitate work with all our libraries and project in general. Also installed was ESLint, that's tool for static code analysis that identify problems in its. This technology helped us to greatly improve the performance and quality of coding our project.

One of the most important factors considered when creating programmes is their design and ease of use. Therefore, we decided to use the ANTD components library.

ANTD is a component library that used together with the React framework. It has a large amount of components for creating interactive interfaces in web applications. Also, this library is supported on all popular browsers and even in desktop applications that are developed on JS. The library helps us customize the high-quality adaptive design of our program Figure 10.

Software testing.

The developed system has the following main functions. First of all, this is a display of information on the air alert on the map of Ukraine. It can be viewed in two modes: "Live", that is, in real time, and also select a certain date to check the presence of an alarm at that time. To check if this is really the case, you can pay attention to the indicator, if it "lights up" red, we are viewing the map in real time. If you need to select a certain date, the indicator will turn gray.

You can also choose the interval in which you want to check existing alarms that have been going on for a long time, or that have occurred only recently.

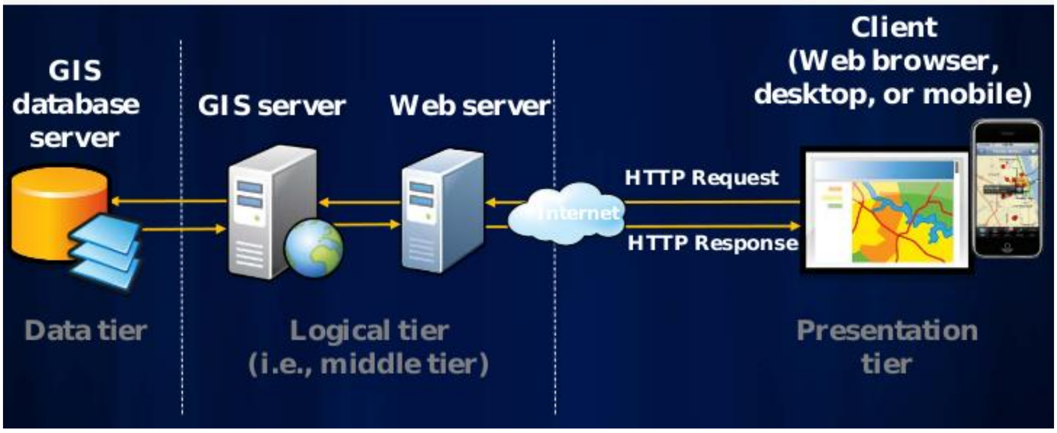

Figure 9: The geographical visualization information system

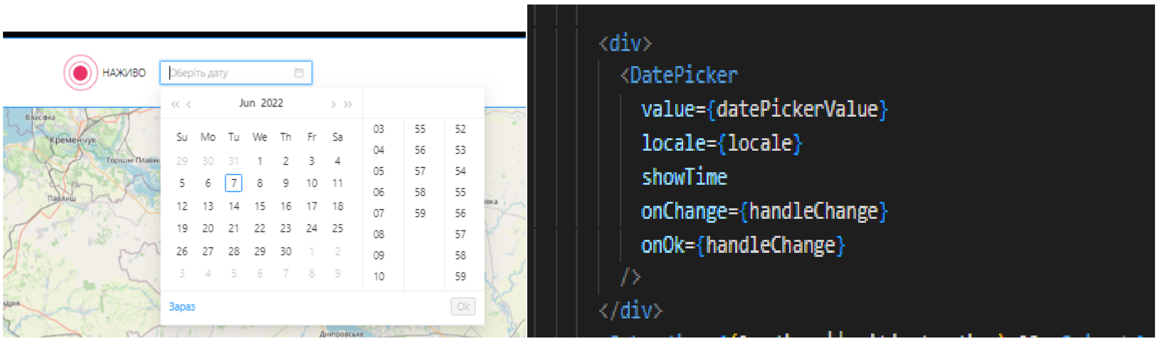

Figure 10: The example of using ANTD in program

7. Conclusions

Development of the geographical visualization information air alarms system has resulted in the model of geographical information system represented in the form of a cortege. The two data models in GIS were investigated and compared with each other, namely vector and raster models. The authors investigated the methods of data interpolation with raster and vector GIS data, and defined the conditions of their application. It was concluded that for the GIS visualization it is preferred to choose a vector data display system.

Based on the research, the authors created the model of visualization of geographical information air alarms in the form of a web application, which informs about the presence of air danger in a certain area and at a certain time. It is determined that GIS is a distributed information system. Many different technologies were used for its creation, which are closely related to the visualization of geospatial data. Future upgrades would include adding a statistic's package and problem solving software to solve problems with the initial design.

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