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New Technologies in 3D Mapping

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Abstract. Among cartographic works, three-dimensional panoramas should be marked out as a special kind of map, which are characterised by visual modes of representing objects in space. The main principles of the creation of both hand-painted and automated maps vector and raster graphics software (Corel Draw and Adobe Photoshop) are considered in the paper. The use of modern information technologies has several advantages over traditional mapping.

Key words:
three-dimensional maps,
principles of creation
of 3D maps,
information technologies,
raster graphics,
vector graphics

Introduction

The tourism industry is one of the most dynamically growing and promising sectors of the economy. For many countries tourism has become a powerful source of state revenue. It has a huge impact on the development of transport, construction, communication and trade and, at the same, time tourism is a form of international co-operation: the geography of travel expands, embracing new districts, countries and regions. With the development of tourism the production of souvenirs is also expanded. Among those, cartographic publications occupy one of the main places, having both artistic and educational value.

The time when maps were created manually, using technical means only available to cartographers and printers, is gradually recedeing into the past. In the world of computer technologies, modern methods of map creation primarily aimed at a wide range of consumers have increasingly become popular. The application of such techniques has several advantages over traditional mapping but, at the same time, images created via modern computer technologies don't lose their artistic value in our time.

Among cartographic works a special kind of map should be identified. These are known as three-dimensional maps (3D maps) and are characterised by their visual modes of presentating objects in space. There are two basic ways of constructing three-dimensional cartographic models: the mathematical modeling (block-diagrams constructed in an XYZ coordinate system, for instance) and psychological (or illusory) modeling, which deals with the visual illusion of a stereoscopic image observed with the naked eye. The psychological (illusory) type of modeling contains the pictorial-artistic principle, which allows spatial objects to be displayed on a plane through a pattern and a colour (volume, background, and lighting). Thus, the image obtains three-dimensionality, i.e. the perception of a real stationary object in three dimensions – breadth, length and height. In relation to the mapping of an

urban landscape it is the opportunity to depict separated buildings and entire blocks with a "bird's eye view".

Cartographers rely on the illusory perception of depth using various graphic techniques for a flat image of three-dimensional objects. This relies on secondary (or psycho-physiological) factors of stereoscopic vision: the visible size of objects, linear and aerial perspective, light and shadow, etc.. Visual or optical illusions themselves are a distorted perception of the essence of the observed objective reality and a cheating of vision.

In three-dimensional mapping it is necessary to rely on such illusory visualisation, in which the observer, looking at a flat two-dimensional image would perceive it as three-dimensional and be able to think about the depicted external three-dimensional forms.

The graphic artistic image is a form of reflection of reality which uses graphics in a process of artistic creation. Visual perception of the object always includes not only the subject but also a certain part of the background. The contour of an object, which is limited to the line in the figure, is an initial overall feature, as the source both for visual and for tactile perception. The formation of an image in perception is a complex process which includes such factors as distinction of the subject from the background, estimation of proportions, lighting and detail separation, which comprise the depicted subject, and the choice of graphic tools for the task, etc.. Informative properties of map images are estimated by the quantity and quality of the information inherent in them. The informational properties of three-dimensional map images are defined primarily through the content of various spatial characteristics. They depend on the degree of generalisation of the reality, including the third dimension. The problem of visualisation of volume is solved in three-dimensional mapping (Kozieł 2003).

Accordingly, the paper is devoted to the variety of cartographic products and the methods of their making by means of modern information technologies. It also deals with the application of vector and raster graphics computer programs in the creation of three-dimensional map images. Experimental work conducted for a three-dimensional map of the historical and cultural heritage of the Republic of Belarus – the Palace and Park complex in Nesvizh – was chosen as the main object.

Sources and Method

Nesvizh Palace and Park complex as a subject of study was not chosen randomly. Nesvizh town, which received the status of cultural capital of Belarus in 2012, is one of the most popular tourist centres in the country. There is a variety of activities dedicated to all the arts. Special attention is drawn to the Palace and Park complex of the Radziwill family, which was renovated relatively recently and opened its doors to the public: each year the number of visitors is about 400,000 people from Russia, Poland, Ukraine, Lithuania, Germany, China and other countries. In 2005 the Nesvizh Palace and Park complex was added to the List of World Cultural Heritage by UNESCO, thus becoming the third Belarusian object in the List, after the Belovezhskaya Pushcha and the Mir Castle.

According to analysis of the panoramic images of different artists in different periods, we can pursue the dynamics of the development of three-dimensional maps, and identify advantages and disadvantages of various techniques from the point of view of visualisation, informative and artistic value of the final product.

Three-dimensional representation of an area (landscape) began in the middle ages. At that time the first cartographical images of cities appeared. They were made by hand, by means of engraving on wood, then on copper. Such maps of cities, for example, formed the Atlas "Civitates Orbis Terrarum" ("Cities of the Earth"), which was issued in the 16th century in Cologne (Brown 1979). Also known are many panoramic images of cities in North America, included in Reps's world-famous atlas (Reps 1998) (Fig. 1). The 20th century marked a new stage in the development of three-dimensional mapping. The first theoretical developments in this field belong to Raisz, Imgof, Robinson and Smirnov. In the Western school of cartography in the 20th century the most famous artists-cartographers were Eduard Imhoff and Heinrich Berann. Imhof was one of the most prominent representatives for creating a realistic image on a map (Imhof 1982). In the late 20th

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Fig. 1. The map of New York, 1856

century the publishers "Bollmann-Bildkarten-Verlag" (Germany), "Terra-Nostra" (Poland), Unique Media (Canada) and others also worked successfully (XXIII International Cartographic Conference: abstracts of papers 2007).

L.E. Smirnov from St. Petersburg University should be mentioned as a leading theorist in the Soviet school of cartography. He considered a number of issues of display space in cartographic works, the classifications of three-dimensional models, various principles and methods of reproduction of three-dimensional objects on maps in his book "Three-Dimensional Mapping". Smirnov noted that the most frequently three-dimensionality was reproduced by plastic techniques, simulating volume. The use of various graphic techniques contributes to the illusory perception of objective reality, in which the observer, looking at a flat two-dimensional image (with some strain of the imagination) is able to perceive it as three-dimensional. He also described the techniques for constructing a perspective image of relief (Smirnov 1982).

Despite the achievements, some researchers have noted that the theoretical knowledge in the field of three-dimensional mapping is just beginning to develop. At present there is no systematic review of graphic settings or accurately designated cartographic principles, which are relevant for 3D maps (Capstick et al. 2007; Häberling et al. 2010).

Swiss scientist C. Häberling was engaged in the methodology of creating interactive three-dimensional maps. In his article he researched the basic design aspects – a group of settings which have different effects on the position and view of objects on the map (graphical view, light-shadow, atmospheric phenomena, etc.). Every design aspect consists of its set of graphical variables, such as slope angle, degree of abstractness, direction of lighting, and others. The basic elements are point, line and polygon with certain characteristics (shape, size, colour, brightness, location, texture). C. Häberling has formulated 19 cartographic principles for 3D maps on the basis of selected graphic variables. Many of them are also used in the preparation of handmade cartographic images; example, the average angle for a perspective view should be about 45°, and the lighting of subjects is preferred from the side or slightly in front, and so on.

One of the first maps made in vector graphics, was a panoramic view of Denver's downtown,

which was published in 1996 by "Pierson Graphics Corp." (USA). A plan-scheme of Karaganda (artist Yuri Lenev, publisher CITY-ZTOO "PEGARO", Kazakhstan) and schematic map of Nizhny Novgorod (publisher LLC "Portfolio", Russia) were also created using vector graphics. The distinctive feature of these maps is the smooth or textural filling of backgrounds (grass, roads), and the lack of shadow plastics; in the panorama of Karaganda city there is also the presence of the same cloned trees and buildings, so the image creates the impression of being from a computer program. The Bulgarian resort "Sunny beach" map (2005) is created using the three-dimensional modeling program 3D Max. The map was assembled from separate pictures of the hotels, while for displaying sand dunes and forests appropriate textures are used.

Thus, three-dimensional mapping, including computer mapping, is an unusual occurrence in modern cartography. All kinds of images of an area combine evident, informative and objective methods of representing reality, but combinations which include the use of perspective are the most successful. Therefore perspective view is often used in the creation of tourist maps: guidebooks, advertising editions, etc. (Atoyan 1999, 2007).

From the scientific point of view, the following directions in study and promotion of the perspective image are of interest:

- the development of a theoretical basis of perspective;
- research into the perception of objects in three-dimensional reality;
- automation of methods of contructing perspective.

Currently, the main emphasis in 3D maps is on consideration of graphic receptions are used in the perspective construction of a district, where it is important to communicated the depth of the image truthfully. Imitation of the depth in the image is reached through colour effects (via principles of air and colour perspective) and graphic receptions (via visual codes of depth) (Atoyan 1999).

There are physical and geometrical perspectives. The physical (air) perspective is the influence of air on clearness of subject outlines and their colour, depending on distance. This means that the "principle of air perspective" is based on a essential tendency to interpret colour changes (contrast of dark and light tones, for instance) as the removal of objects (Keates 1984).

Geometrical (linear) perspective is associated with a reduction in the size of subjectswith the increase of distance from the subject to the observer. Air and linear perspectives have become an essential part of the works of many artists. The visual codes of depth constitute the complexity of graphic receptions, which is used in the construction of three-dimensional images.

During the construction of perspective it is necessary to generalise the images depending on scale. The scale varies on panoramic maps – from large in the foreground to small in the distant background. The diversity of the image is communicated with the application of visual codes of depth – the relative size and interposition of objects. From three to seven depth fields are usually selected depending on transmitted depth of the image, which, in turn, depends on the inclination of the picture plane. The gradual transition from the foreground to the most distand field is carried out by the following graphic means: reduction of activity of lines, schematisation of the image, reduction of intensity of shading, removal of detail. Using gradation of light exposure and the rule of construction of shadows, it is possible to achieve an expressive and volumetric shaped figure. The height of the sun above the horizon and, consequently, length of shadows, testifies to the season or day, which can be used to manufacture panoramas for different seasons (for example, winter and summer variants of panoramic maps) (Atoyan 1999, 2007).

Cartographic products demand an individual approach to the construction of the perspective image depending on territorial scope, the character of the district, and thematic information. The drawing up of the perspective image is a difficult process, which can be implemented by highly-qualified cartographer-designers. Along with this, the distinctive feature of our time is the introduction of computing and information technology to all fields of scientific activity and sectors of the economy. The traditional methods of creating cartographic products, which were based on manual labour and the production experience of cartographers, cease to meet modern requirements. These methods do not provide a full solution to cartographical tasks, such as: modern design, high quality colourful edition, the efficien-

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cy of mapping, compact storage of cartographical information, ongoing operational updating and reuse, etc. Moreover traditional technology is characterised by the cumbersome process and high input of work, and the time and the cost of map creation are significantly increased.

The widespread implementation of new technologies in cartographic process at all stages of map creation can significantly reduce the work cycle, and improve the efficiency and the quality of cartographic products. As a result, in the theory and the practice of cartography, the need to reconsider and develop technology has appeared. These trends and the impact of computer technology have become the origin of the new field of cartographic science and production – so-called computer cartography, which is based on modern high-speed computers and other means of graphic information processing (including suitable software).

The use of personal computers has exercised a significant influence on cartographic production. At present we have the opportunity to process a body of information in an interactive (online) mode, to get high-quality pictures, to store information in digital form for a long time, to use it for map creation repeatedly and to eliminate expensive and routine manual processes. It is possible to use both vector and raster software to create three-dimensional cartographical images. The choice of program is determined by the features of the image and the cartographer's goal.

Raster graphics are the most realistic way to display all surrounding objects. It has rich visualisation capabilities. However, only high-quality raster images can convey the diversity of processes and phenomena perceived by the human eye. "Adobe Photoshop" software is a professional graphic editor intended for photo processing and the creation of original illustrations. Today the software is almost a standard tool for designers, artists and cartographers dealing with the processing and creation of images. In three-dimensional mapping, Adobe Photoshop is used for digital handling of scanned images and qualitative colour design which is close to a hand-painted map in texture and construction of perspective projection (Fig. 2).

Vector graphics have higher quality and a fundamentally different principle of image formation. Even the most complicated image can be created through combinations of simple graphic elements drawn on a screen. Moreover, during the vector editing, it is possible to change picture size without losing quality. Images designed exceptionally in the vector, could be used both in small guidebooks and in large-size products, such as wall maps or billboards. The disadvantage of vector graphics is manifested in the difficulty of transmitting realistic images. The attempt to transform a photo into a vector format leads to a significant increase in the size of the file because of the huge number of elementary objects which the image contains. Corel Draw software is one of the most popular graphic editors. The program offers a rich set of tools, methods and means for construction and editing an image (including cartographic pictures) and provides a simple and convenient user interface. There are appropriate tools for editing the picture, colour of contours and background fill, clicking on which opens an interactive window of image settings. Choosing a vector editor, preference is usually given to the familiar software product; this choice is in large part due to the habit of using the particular program in which the user created the set of documents.

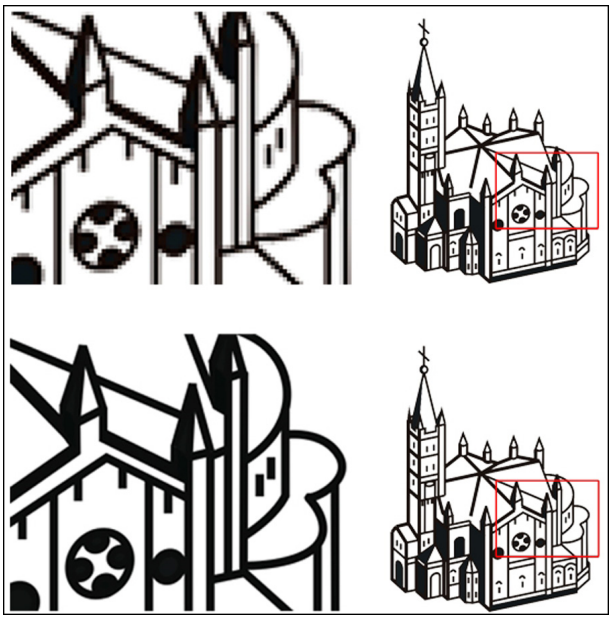

Fig. 2. Raster (a) and vector (b) images of an architectural monument on the example of the church in Potsdam (drawing by authors)

Results and Discussion

The combined hand-made and automated technology for creating a three-dimensional cartographic picture provides several levels of image visualisation, which are presented in Figure 3. They are built on the principle of "from general to specific", "from simple to complex" and represent a gradual transition from two-dimensional maps to three-dimensional models. The first level of visualisation involves transforming the base-map into the selected projection – perspective or axonometric; the second level involves the automated creation of a framework of model buildings (currently the GIS applications exist by which, with the coordinates of 2 corner points of a building and the number of floors, you can quickly build a "box" of the whole block). The third level of visualisation is the filling of facades with constructive linear signs from the library of elements; the final, fourth level involves the filling of contours with colour elements and textures

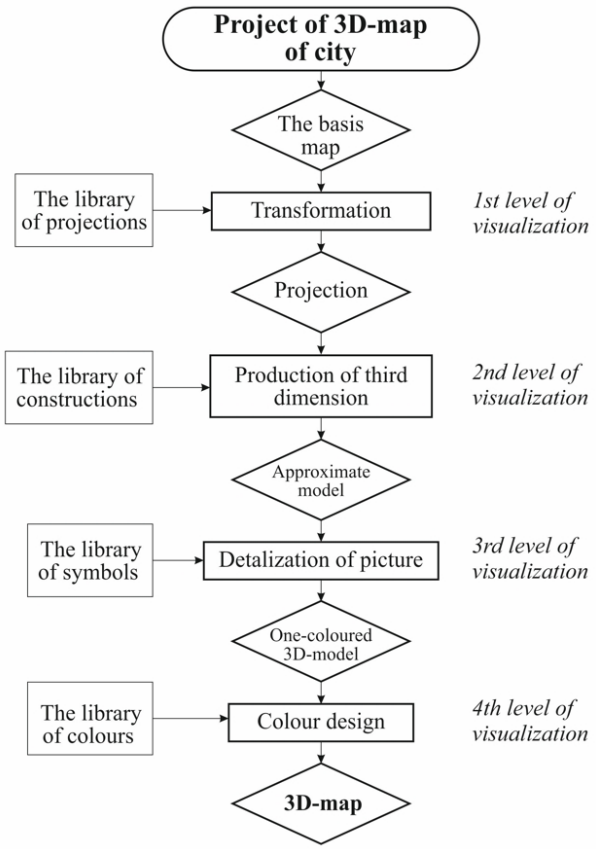

Fig. 3. Creating a three-dimensional map image; levels of visualization

from the corresponding library of colour elements. Complex designs for any building, e.g. religious monuments, can also be constructed separately in the 3D Max program, and can then be included in the overall image.

The technique of creating both hand-painted and computer panoramic maps of an urban landscape can be divided into several practical stages. In the first, the materials are prepared. As Häberling noted, when you create 3D maps special attention should be given to the selection of raw materials (the model of the earth's surface, photographs, satellite imagery, scanned topographic and thematic maps, etc.). The design, visual appearance, usability and accessibility of cartographic works are also important, in his opinion (Häberling et al. 2010). They need to identify the characteristics of the territory and to simplify the field research. Among such sources topographic maps and plans of cities, and photos from space (for example, www.maps.google.ru, www.bing.com/maps, etc.) are well-known. Buildings, the shapes of roofs, the road situation, parks and individual trees are clearly represented on them. It is also important to choose a point of view and territorial coverage.

The second stage is the field investigation of the district, which supposes a visit to the city – in other words, all its streets and parks – to display them on the map. A lot of photos (or videos) are taken during this process. All field materials are processed and systematised.

The cameral stage consists in the process of map composition and includes the following activities:

– construction of a mathematical framework (the perspective projection);

– implementation of a line sketch (by pencil, technical pen or graphics tablet);

– colour design of the original.

With the introduction of automation techniques in mapping, many stages of map creation can be performed using a computer. For example, a database can be used to store and retrieve a body of information (photographic, cartographical and text); suitable software allows a schematic representation of the future map to be created, a perspective projection to be constructed (in Corel Draw) and a colour scheme to be designed (in "Adobe Photoshop").

The projections can be constructed on the basis of the topographic plan of the district, which is ori-

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entated with the same viewpoint as the perspective map (Fig. 4). The workspace, with all its objects, can be transformed into a perspective view by means of the special option "Add Perspective".

Then the primary volume visualisation is transmited to depicted objects: the number of floors of the buildings is determined, and the height of the buildings is represented depending on the object's location on the map. After that the profiles of the roofs are displayed.

After the creation of the frame of the buildings (schematic cartographic base), the facades of the buildings are filled with structural elements (windows, doors, various decorative elements). For this purpose it is reasonable to create a library of symbols, which consists of various types of elements in the vector (Fig. 5). Corel Draw allows the user to copy the necessary vector symbol and to distort its contours to a perspective view via appropriate options.

The final visualisation of the objects of an urban landscape is achieved with a colour scheme of the image. Painting of the map can be done in both vector and raster graphics programs. The differences are only in the perception of the resultant images: the smooth, uniform fill of the objects in the vector, and the effect of hand-painted works in raster textures. In this case it is also efficient to create a

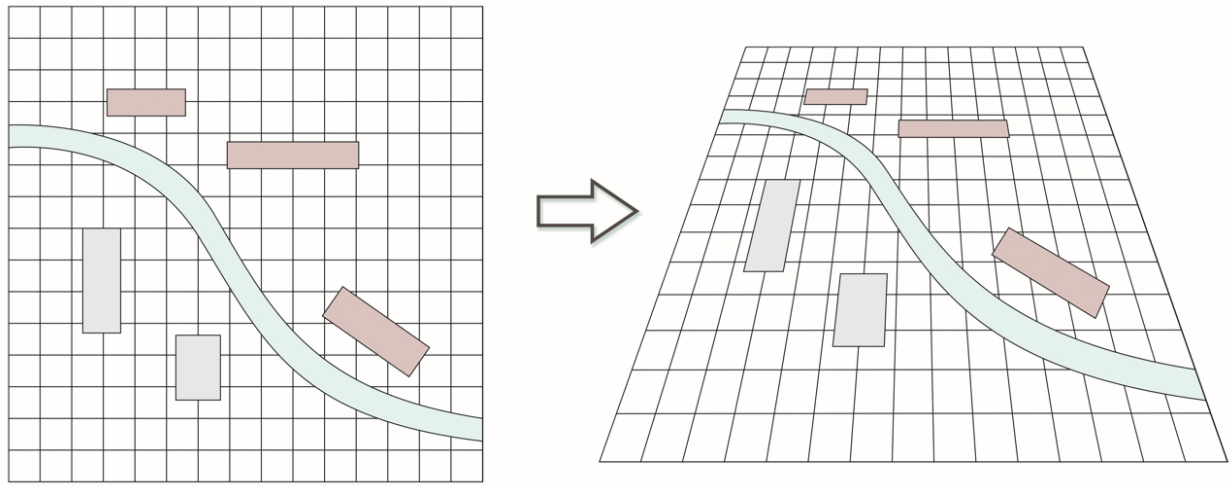

Fig. 4. Construction of a perspective projection in the program Corel Draw (map transformation to the central perspective – the 1st level of visualization)

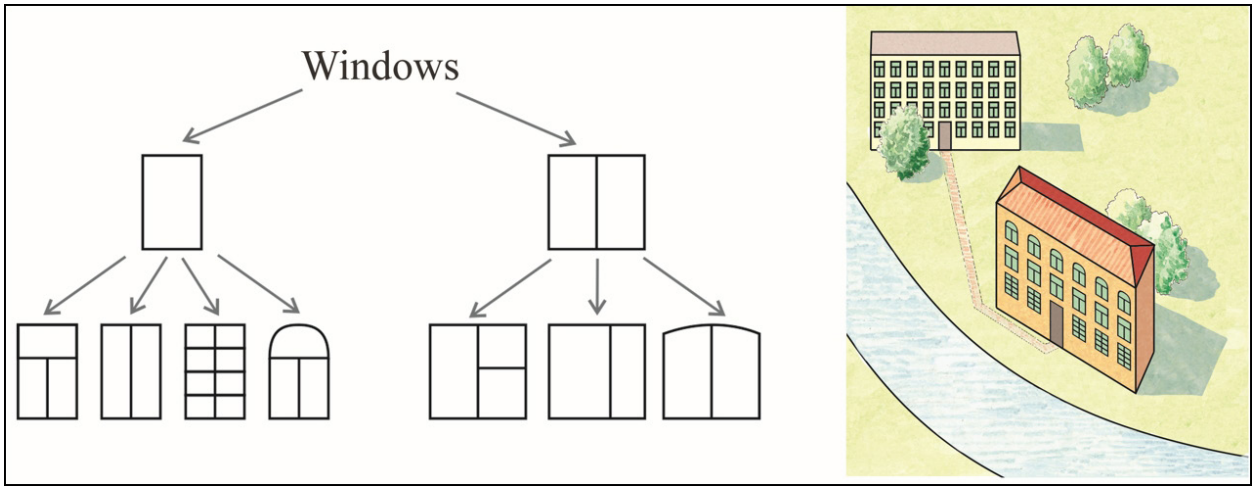

Fig. 5. The fragment of the library of symbols in Corel Draw and construction of the image (the 2nd, 3rd and 4th levels of visualization)

library of colours and textures (for example, roads, hydrography, grass, roofs, and object shadows).

All of the above stages provide the construction of the three-dimensional image of the Nesvizh Palace. The initial source of information to create a three-dimensional image is the plan of the Palace. An orthogonal image demonstrates the architectural features of the building, and serves as a base for vectorisation of its contours.

The overall scheme of creation of 3D maps of the Palace in Nesvizh can be represented by several stages (Fig. 6). The first implies the conversion of outlines of the castle into vector format, and then the image in orthogonal (plan) projection is transformed into a perspective image. Further, the contour drawing is built in the Corel Draw vector program on the basis of numerous photographs, satellite images and sketches of the castle; the contour drawing includes basic lines, giving a sense of

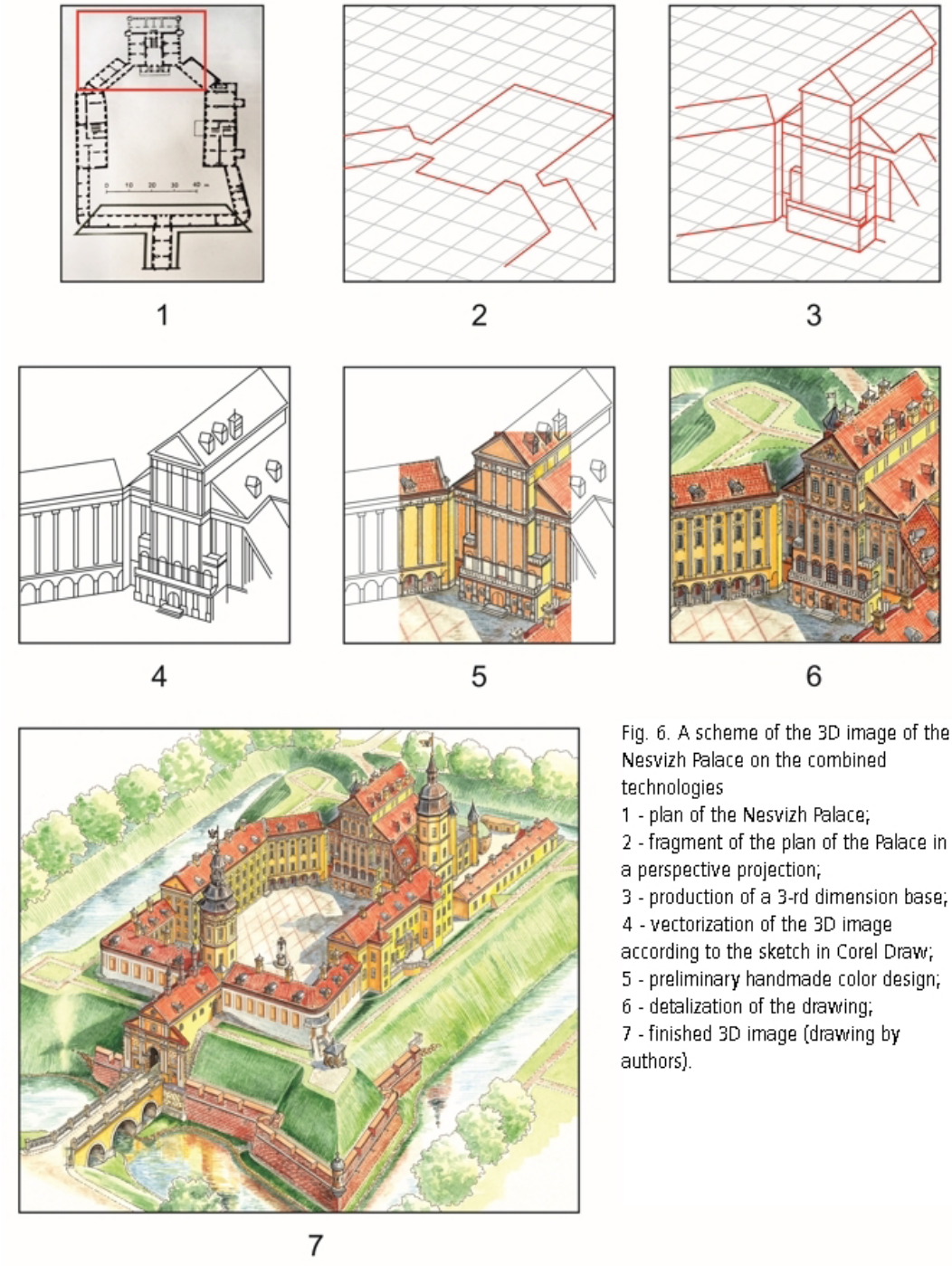

Fig. 6. A scheme of the 3D image of the Nesvizh Palace on the combined technologies
1 - plan of the Nesvizh Palace;
2 - fragment of the plan of the Palace in a perspective projection;
3 - production of a 3-rd dimension base;
4 - vectorization of the 3D image according to the sketch in Corel Draw;
5 - preliminary handmade color design;
6 - detalization of the drawing;
7 - finished 3D image (drawing by authors).

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depth (the edges and faces of walls, roofs; the content of the facades, such as columns) to the image. The vector drawing is exported into the PNG format excluding the background (i.e. keeping the lines on a transparent background).

A general colour scheme is developed in the next phase. Here it is advisable to create a hand-painted palette of colour. Watercolours are applied to small arrays of colours which match the faces of different exposures (lit and shaded walls, roofs, the texture of the platform and falling shadow). Using this palette allows you to simplify the process of colouring picture, but it gives the image a handmade appearance due to the natural irregularities of colouring and a smooth transition of shades.

At the final stage of the creation of the three-dimensional image of the Nesvizh Palace, pattern is complemented by structural elements from the symbol library (windows, doors, arches of different size and configuration). Detailing of individual elements, such as bas-reliefs on the main facade, completes the process of 3D map creation.

Taking into account that cities change rapidly, let us briefly dwell on the technical features of the updating of three-dimensional automated and handmade maps. The changing of the urban environment (restoration, renovation and construction of buildings, creation of new park areas) requires the updating of maps.

Significant difficulties are caused by making major changes manually in the original image of the city and creating a new drawing, not fundamentally different from the original. In this case, we cannot do it without special raster graphics software. Working with the digitised image (usually in TIFF format), you can do some operations without any difficulty, such as "to erase" a missing tree or, conversely, "to put" a whole alley, "to repaint" the facade of the building, "to replace" a sloping roof with a flat roof and more, which cause some problems during the manual updating of a map.

The updates which need to be included in the new version of any panoramic map can be divided into several groups according to the degree of difficulty. New buildings would best be drawn separately and from the same point of view, in order that the image not differ from the overall style of the map. Subsequently, this picture is pre-scanned in high resolution (300 dpi – dots per inch at least) and saved in TIFF format, then in a computer program the picture is superimposed on a digitised panoramic map in the corresponding place. Next, the scanned image is opened in Adobe Photoshop. For the convenience of combining the picture with the panorama, the objects (blocks or individual buildings) are cut along the contour by the "Polygonal Lasso Tool" and copied to a new layer, which is subsequently dragged into the panoramic map using the "Move" tool. Now you can work directly with the image, which is located on a separate layer, in the main file without harming the original. First of all, the "cut" object is adjusted in size and combined with the basic guidelines. Then the required colour and contrast are assigned to the pattern to make it closest to the original image. This purpose is served by the submenu "Image – Adjustments".

Smaller changes, which, as a rule, are the vast majority, are entered directly in the program with no manual drawing. They include the editing of individual objects and their parts: colours and patterns of rooftops and facades of buildings, road junctions, parkland and individual trees. A variety of tools can be applied depending on the task and the nature of the object. So, in order to change the colour of the roof, it is advisable to use the option "Replace colour" (submenu "Image – Adjustments").

The dialog "Replace colour" contains tools designed to highlight a colour range to be replaced globally, as well as the scale of the key attributes of colour (hue, saturation, brightness). This method allows to preserve the texture of the picture and the fine elements of the original image and to change the basic colour without distortion of the contour lines.

Some updates, such as changes in the road network (new junctions, streets, footpaths and park paths, etc.) are made by hand using a graphics tablet. Key lines are drawn on a separate layer which is located on top of the original and all of the "white spots", which inevitably occur during the change of scenery, are filled with the relevant textures using "Clone Stamp Tool". This tool is designed for applying one part of the image on top of another. For filling large areas (for example, grass in parks) it is advisable to use the fill (in this case, the texture of the grass).

Either "Polygonal Lasso Tool" or "Clone Stamp Tool" is used for "reproduction" of trees and entire forests. In the first case, the necessary objects are selected on the panorama, and for convenience are copied to a new layer and transferred to the right place. By analogy with scanned drawings, the colour and contrast of these data objects, which will be closer to similar objects in the immediate vicinity, can be changed. Individual trees merge with the main image by combining layers and only after making the necessary changes in their shape. Unlike this method, "Clone Stamp Tool" allows painting only on the top of the original, on the same layer, resulting in knock-on changes.

Conclusion

Thus, the usage of a perspective image opens wide possibilities for the creation of tourist maps. Perspective has the following advantages over other types of image:

- the perspective image is evident; the perspective view graphically displays objects in reality;
- the graphic methods are accessible and understandable to all;
- all elements of a landscape can be shown.

The most essential lack of panoramas is variable scale; therefore it is expedient to issue such a production in conjunction with exact metric maps: topographical or reference maps, plans of cities and architectural drawings of castles, temples, etc.

The main principles of creation both of hand-painted and automated maps are considered in the paper. But it is necessary to note that the automated ways of manufacturing of illusory three-dimensional cartographical products will be increasingly developed in the future.

Using modern means allows the implementation of several types of activities in an interactive mode on the digital model of a district, such as:

- determination of parameters of perspective;
- accumulation and systematisation of used materials on digital storage devices;
- readiness for prompt and high-quality editing (scanning of the original map, arrangement of tourist information, advertising modules etc.).

Moreover, nowadays more attention is paid to 3D mapping of terrain for the purpose of online display (on the Internet) or in mobile applications. These aspects are substantially dominated by scientists from Sweden, Switzerland, Germany, France, USA, UK and other countries.

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