Visualization of process maps for construction and installation works

S A Sinenko and S A Aliev

1 Moscow State University of Civil Engineering, 26, Yaroslavskoye sh., Moscow, Russia
2 Grozny State Oil Technical University named after M.D. Millionshchikov, korp. 1,100, prosp. Husejna Isaeva, Grozny, 364068 Russia

E-mail: sasin50@gmail.com, asa-fenix@mail.ru

Abstract. The article presents the principles, methods and means of visualization of organizational and technological solutions developed as a part of technological maps for the production of construction and special operations. In this paper, the authors analyze the possible ways of the development of visualization of organizational and technological solutions. The examples of 3D images of the main production schemes as a part of technological maps for the installation of beams in machine rooms in the building of hydroelectric power plants are shown. The developed display techniques can be used in the practice of the design of technological maps for the production of construction and special operations. This technology will expand the scope of modern design tools in the practice of construction production.

1. Introduction

The quality and cost of the construction project and its components are largely determined by the applied design technology. Previously, all technical documentation was created manually on drawing boards. Currently, when PCs are located directly at the workplaces of designers and technologists, any project is impossible without the use of computer-aided design (CAD) systems.

In the Russian Federation, such systems appeared as a “progressive tool to accelerate the work of designers in the early 80s of the last century. The main objective of CAD was reduced to the creation of the external surfaces of buildings and structures and their elements, strength calculations, later these systems made it possible to calculate various design schemes in order to create architectural and construction drawings, captions and dimensions, and also produce finished and completed drawings in accordance with the requirements of existing standards.

The use of CAD allows increasing the productivity of a designer and technologist by 2–3 times, increasing the efficiency of interaction between different departments, the level and quality of design work. With the help of CAD, it is possible to shorten the preparation time for construction production, free designers, expand the design and manufacturing capabilities of complex equipment, as well as create a unified design and technological base for construction and design organizations, which, of course, will positively affect the financial position of contracting organizations.

The progress of computer technology and its development over the past decades has emerged as a means of the improvement of the design process, dramatically increasing the efficiency of the intellectual activity of a designer. Finally, it becomes possible to use virtual reality technology as a
The idea of direct design appeared as a result of the analysis of the use of virtual technology as a tool for the visualization of design decisions on the organization and technology of construction production [1]. It is based on the immersion of a civil engineer in the designed environment. An engineer being inside the projected space, determines the direction of the changes and implements these changes interactively, moving the forms in the virtual space. The implementation of the idea of “direct design” is supported by many studies in the field of virtual reality [2–12].

2. Methods and materials

As it is known, as part of the organizational and technological documentation, in particular, production work plan (PWP), a technological map is developed for the production of the most complex construction and installation works and special operations, reflecting the methods and techniques for the performance of construction work, which indicates the scope of application, the plan, means and methods of construction and installation works, work flow schemes, temporary inventory devices, machines, mechanisms and equipment temporary areas for warehousing and site joints, movement of assembly cranes and mechanized installations, devices and safety instructions.

Modern software systems “Hector-builder” (HMI, PWP, HMI CAD and others), NanoCAD, “Builder” and others allow improving the design and development of technological maps for the construction and installation work [5–10].

The main principle for the development and rationalization of process control and management documentation (PCMD) is the maximum reduction of manual labor of designers, increasing labor productivity in design and construction organizations, reducing the duration of design and improving the quality of PCMD. The improvement tool should be presented by the methods and technical means based on the use of computers, peripheral devices, reprography and organizational equipment, which allow combining the technological process and reproduction of documents into a single system [3].

The main conditions for rationalization are: the use of planar prototyping and documents – blanks, electrographic apparatus for the production of originals, microfilms of enlarged copies of documents, as well as aperture cards as a means of the automation of the copying and storage of documents [6–10].

The “Hector: Designer-Builder” program provides construction planners with the latest technologies for the development of all sections of construction management plans (CMP) and production work plans (PWP), including construction general layouts.

One of the modern directions in the development of computer graphics is the construction of photorealistic images of objects modeled on a computer [1].

This is relevant for computer aided design, motion-picture industry, advertisements, design, computer games, etc. The increase in the quality of computer graphics products is rapidly spreading in the field of practical application, and the requirements of users for realistic 3-D images are constantly growing [2].

The growth of computing power allows solving increasingly complex tasks of visualization of three-dimensional scenes (the number of objects, light sources, image resolution), the increase in complexity of the tasks themselves is ahead of it.

There are two main approaches to the visualization of 3-D models:

- The creation of pseudo-three-dimensional fragments, with their subsequent processing according to the principles of two-dimensional graphics, with little use of the simplest laws of the third dimension;
- The creation of a model of a three-dimensional world, with its further projection on screen. All modern three-dimensional games are developed in this way.

The creation of animation is a complex process, requiring attention to detail. It is frame-by-frame arrangement of objects of construction general layout, setting the trajectory of their movement and interaction with the rest of the 3D model. Depending on the power of the computer, the quality of animation and visualization can vary from photorealistic to a schematic demonstration of the capabilities of software package.
Creating an animation, it is necessary to consider what is needed to get in the result, namely, it is necessary to calculate the time of the finished animation. It is recommended to perform all the calculations in advance, before starting the animation on render, since this is a very long process. In order to save machine time and resources of their workstation, many people use video editors and edit a ready-made video file, stretching frames, thereby slowing down the movement of objects. This method has both pros and cons. The advantage is time and resources saving, and disadvantage is the resulting video.

Thus, the required number of frames was not calculated in advance, the video editor has nothing to fill in the gaps between the frames, which as a result lead to a jagged non-realistic video. A smooth and beautiful video is much preferable to both an outside viewer and a designer.

According to the above-mentioned aspects, we can conclude that the creation of any animation begins with the calculation of time and number of frames. Thus, in order to create a five-minute animation, it is necessary to take into account that the optimal number of frames per second is 30. Using simple arithmetic calculations, we get a finite number of frames equal to 9000. It takes about 30–33 seconds to calculate each frame on a modern computer, which implies that 9000 frames video is created in about 75 hours.

It is recommended to perform the creation of a visualization of the process of building a hydroelectric power station in the reverse order. That is, the building on the animation should not be built, but disassembled. This is the right approach to the visualization of the construction process. With this method, it is possible to avoid a heap of objects and, most importantly, correctly display the construction process.

In addition, it is necessary to take into account the computing capabilities of a working computer. To save machine resources during the calculation, a camera is created on the 3D model, within which the final image will be calculated. Thus, it becomes possible to avoid rendering the invisible sections of the created model and spend all the useful computer power on the calculation of the required image.

The camera is also an object of the 3D model and has its coordinates in space. Having set the coordinates of the frame-by-frame motion of the camera, we get an animation showing the existing position. It is customary to use such animations at the beginning and end of a video to show visually the difference between the starting frame and the ending.

The construction process chart is not created without the location and calculations of the used construction equipment. In animation, its presence is also necessary, since without technology it is impossible to display realistically the process of the construction of a building.

The important stage in the creation of animation is a frame-by-frame arrangement of interaction objects with a building model. It is necessary to set the interval of occurrence of each object and each part of the model at exact time. For example, the first object is a crane, which begins the installation of a crane beam. It has a trajectory of motion and the disappearance of the interacting elements, building structures, is configured on the key frame. Thus, after processing and inverting the visual range of video file, the effect of the assembly of industrial building is achieved.

This technology is one of the first steps to improve the design of technological maps for the production of construction and installation works.

One of the modern directions in the development of computer graphics is the construction of photorealistic images of objects modeled on a computer.

Although the growth of computing power allows solving increasingly complex tasks of visualization of three-dimensional scenes (the number of objects, light sources, image resolution), the increase in complexity of the tasks themselves is ahead of it.

Nowadays, the most common 3D modeling method is to lay out partially the basics of vector graphics. It is performed in the following way: any three-dimensional model (which, ultimately, builds up the virtual world consists of) is represented as a certain number of intersecting planes. The excesses of planes are cut off. As a result, two-dimensional polygons remain, placed in a three-dimensional coordinate system.
One of the main directions in the development of computer graphics is physically accurate modeling of light passage in various environments.

According to the final indicator, it was found that Autodesk 3D Max became the software environment for the realization of the virtual reality of construction general layout during the construction of an object.

Developing since the 90s of the last century, the package of three-dimensional modeling 3D max has already reached a certain level of excellence. This is confirmed by its current popularity in the thriving industry of film, television and computer games. Impressing with their believability, 3D special effects of TV screens, the unimaginably realistic virtual reality of three-dimensional computer worlds, as well as numerous high-quality architectural and design projects implemented using the 3D max package, have firmly entered our lives [2,3].

Modeling usually takes from 50% to 80% of the entire workflow. It is important to understand that the time spent on modeling, firstly, depends on the complexity of the situation during the installation of structures, on the building or premises, and not on their size. The time for texturing the model depends on the complexity of the materials and their diversity. A one-story industrial building is much easier and faster to texture than a small cottage with several types of stone and facing bricks.

Visualization involves the adjustment of lighting, surroundings and materials. At this stage, the computer model acquires a photorealistic, presentable appearance, image quality is determined. It can take from 10% to 50% percent of the entire workflow. The quality of visualization directly depends on the experience and professionalism of a designer.

The main components of the cost of visualization are the amount of work and its quality. The process chart of construction and installation works, performed in usual format, contains all the necessary attributes.

With the so-called raising of drawing, it is necessary to know how many and what angles of an object are necessary to depict. This component affects the timing and quality of the displayed virtual reality.

The color scheme includes information on finishing materials and their colors. Here all the basic elements are included: from design to a part of a building, and material samples in the form of photographs are provided.

As a result, it is possible to obtain the images of various qualities. It is necessary to take into account the resources of a power plant. In the case, if the process of the creation of visualization, and later on animation, proceeds on the so-called render farm, then it is not recommended to degrade the output image quality. During the work on a standard computer, the quality of animation decreases, since the computer is simply not able to calculate so many objects.

The capabilities of computer graphics allow creating three-dimensional models of architectural objects of any degree of complexity and organization in a virtual environment.

3D visualization is an important tool for the attraction of investment in a construction project, since investors see not only dry calculations and technical drawings, but also a vivid image of the future building. Sometimes it is very difficult to reveal the concept of a project using only traditional tools, for example, drawings, sketches or photographs of analogues.

In order for a three-dimensional object to be displayed on a screen in real time, it must be represented as points in a three-dimensional coordinate system, where each displayed point will have the coordinates x, y and z. The points of each object, fully setting its position in space, are stored in the system memory. In order to display an object on a two-dimensional screen, it is necessary to form its image (to visualize it).

In order to build simple exterior scenes, it is possible to use templates that exist in 3D Max, starting with the 6th version.

The whole model is designed to animate the process of the construction of an industrial building; all the elements of the building are created separately and are combined into groups.

The visualization of a technological process is a way to display information about the state of technological equipment and process parameters on a computer monitor or operator panel in an
automatic control system in construction, which also provides graphical methods for controlling the technological process. The display system is based on the process mnemonic diagram, a static image in a visually simple and intuitive form, showing equipment elements, possibly processed materials and products, their interaction and processing order. The static mnemonic diagram is animated, reflecting the real state of equipment and raw materials.

3. Results
The presentation of information in 3D is limited to simple and unambiguously perceived colors (red, green, yellow, white, black, gray). In this case, not small font is used in the captions.

The passion for dynamic pictures (for example, animation) will distract and tire a designer of main design solutions. The use of photorealistic images of objects will worsen perception. In order to control the technological process, the mnemonic diagram contains the elements of a graphical interface, most often typical for modern software: input-output windows, buttons, sliders. In addition, events (for example, mouse clicks) on image elements can be used.

In addition to the denominated mnemonic diagrams, the windows, located on top of the mnemonic scheme are used. These windows display the dependences of the process parameters on time, as well as text messages about the state of the system and the actions of a designer. Modern design tools, as a rule, contain built-in editors that allow implementing all visualization tasks.

In this case, it is proposed to carry out work on the creation of a technical map for the installation of beams under an overhead crane in the machine room of a hydroelectric power station in the group of Archicad 19 and Artlantis 6. In Archicad (Archicad 19), a model is created and subsequent code is made in layout, and in Artlantis (Artlantis 6) the visualization of the 3D model is performed. The model was created using standard Archicad tools:

- The top with cutouts for the turbines were performed using the “tops” tool;
- The columns were made using a combination of tools “column” and “complex profile”; 
- The top beams were made using the tool “beams”; 
- The crane was exported as “pdf” element from the finished library;
- The beams for ceiling travelling crane were created using the combination of the “beam of complex profile” tools (for the main body of the beam), “solid modeling operations” were used to create recesses in the upper part of the beams, mounting outlets were created from “cylindrical primitives” from the standard library, rails were created from beams of the special profile “corner”; 
- Scaffolding was created from a combination of elements “top”, “columns of cylindrical section”, “cylindrical beams”; 
- The construction bolt is created using the combination of a “cylindrical column” and “top” with a hexagonal profile;
- The bolt washer is created using “top” with a cut;
- The mounting holes for bolts are made combining a “cylindrical primitive” from the standard library of elements and “solid modeling operations”; 
- The landscape to indicate the location of the crane was created using 3D net tool.

After the model is created, it is exported to the Artlantis 6 program, in which the materials are set element by element and rendered, as well as images are obtained, which are put into a layout in the Archicad and saved in pdf (Fig. 1, 2)

4. Conclusion
The obtained results confirm the effectiveness of visualization of the schemes for the implementation of construction processes as a part of process charts for the construction, installation and special operations. The discussion of the obtained results and approbation proved the reliability of research directions.
Of course, the results are still imperfect (this directly depends on the chosen observation point), but taking into account the effectiveness of this technology, we can assume that the proposed methods and means of display will expand the scope of these techniques in the practice of construction production and will allow getting realistic types of production.

Modern computer facilities and monitors as well as software tools have rich graphic capabilities. Designer full use these features. As a result, it gives more realistic images of organizational and technological solutions in process charts for construction and special operations.

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References
[1] Sinenko S A, Ginzbreg V M, Sapozzhnikov V N et al 2019 Automation of organizational and technological design in construction (Saratov: Higher Ed.) 240 p
[2] Sinenko S A, Kuzmina T K and Oleynik P P 2015 Customer activities in market conditions Handbook (DIA Publ. House) 288 p
[3] Kolesnikova E B, Kuzmina T K and Sinenko S A 2015 The solution of organizational and technological problems. Construction Textbook (Moscow: Ed. DIA) 96 p
[4] Sinenko S, Poznakhirko T and Obodnikov V 2019 Automation of visualization process for organizational and technological design solutions Construction Engineering and Management 2nd Conf. for Civil Engineer. Res. Networks [2018 MATEC Web of Conferences 270, 05008 22 February]. AN 05008 Retrieved from: https://doi.org/10.1051/matecconf/201927005008
[5] Sinenko S A and Feldman A O 2018 Efficiency Perfection of Organizational-Technological Decisionson the Basis of Information Flows in the Construction of Multi-Storey Residential Buildings, IOP Conf. Ser. Mater. Sci. and Engineer. 463 042010 DOI: 10.1088 / 1757-899X / 463/4/042010
[6] Skvortsov A V 2015 BIM data models for infrastructure CAD and GIS for roads 1(4) 16–23
[7] Rumyantseva E V and Manukhina L A 2015 BIM-technologies: approach to designing a building object as a whole Modern Science: Actual Problems and Solutions 5(18) 33–6
[8] Lushnikov A S 2015 Problems and advantages of implementing BIM technologies in construction companies Bull. of civil engineers 6(53) 252–6
[9] Lapidus A A, Telichenko V I, Tumanov D K et al 2014 Development of methods of technology and organization of construction production to solve energy efficiency problems Technol. and organizat. of construct. Product. 2 10–6
[10] Losev K Yu, Chulkov V O and Kazaryan R R 2018 Modeling and Assessment of a Building Intellectual Grade in the Community of Full Participant in Construction Activities IOP Conf. Ser. Mater. Sci. and Engineer. 463 032085

[11] Kazaryan R R 2018 System-targeted approach to the integrated use of transport in the interests of life safety MATEC Web of Conf. 239

[12] Murtazaev S-A Y, Kuladzhi T V, Taymaskhanov Kh E et al December 2018 Advances in Engineering Research Int. Symp. on Engineer. and Earth Sci. (ISEES 2018) vol 177 Retrieved from: Https://doi.org/10.2991/isees-18-18, 2018.48