3D Modeling as Method for Construction and Analysis of Graphic Objects

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Abstract. The use of 3D modeling when constructing and analyzing perspective projections and shadows is considered. The creation of photorealistic image is shown. The perspective of the construction project and characterization of its image are given as an example. The authors consider the construction of a dynamic block as a means of graphical information storage and automation of geometric constructions. The example of the dynamic block construction at creating a truss node is demonstrated. The constructions are considered as applied to the AutoCAD software. The paper is aimed at improving the graphic methods of architectural design and improving the educational process when training the Bachelor’s degree students majoring in construction.

1. Introduction
Today, engineering graphics is characterized by rapid development and introduction of 3D technology in computers. The primary process is to build a realistic 3D model of an object, and the creation of its drawing is a secondary and mainly automated process. 3D model can be transferred to production without constructing its drawings [1,2]. All up-to-date CAD software has advanced tools of 3D modeling, design and automated construction of drawings.

These tendencies are shown also in architectural and construction design. Experience of application of 3D design shows high performance of this direction [3-5]. Examples of successful application of 3D methods in case of the decision of scientific tasks of construction design are known [6]. At the same time in the practice of building design, traditional methods of 2D design based on the primary construction of drawings continue to be used. This reduces the efficiency of design works.

At departments of a graphics when training students of construction specialties transition tendencies from traditional 2D methods to the modern 3D methods of geometrical simulation are also shown [7-11]. Among teachers there is an extensive discussion about the directions of enhancement of educational process [12-14].

Operation purpose: to show some opportunities of 3D simulation in case of a research and the decision of tasks of scientific and application-oriented character in the field of architecture and construction and also the maintenance of the modern training course 3D - training of students of construction specialties.

The research papers taken from the computer graphics course, which is taught in SUSU, are given as examples. The constructions are made in the AutoCAD program.
2. Automated construction of perspective images

Perspective pictures in a traditional 2D modeling are the most complex ones used in the architectural design. 3D modeling in the automatic mode easily copes with their construction for the project of any complexity.

The creation of perspective starts with the construction of a 3D model of an object [15], see Figure 1(a). Next goes installation and configuration of the camera. In the Preview window we find and control the confirmation of the perspective properties [16]: the main beam SP is projected to the point P, direct beams SM and SN are displayed vertically, the main point P in the Perspective window is at the intersection of the diagonals of the viewport and simultaneously on the horizon line and others, see Figure 1(b).

![Figure 1. The creation of perspective by camera installation.](image)

The requirements [15,16] to the choice of the perspective parameters are known. These are the optimal values of the angles α, b, γ, perpendicularity of the main beam SP to MN picture, the position of the point P1 in the middle third of the length of the MN picture, near objects should not cover distant ones and so on, see Figure 2.

![Figure 2. Parametric drawing.](image)

When performing 2D modeling, the error in the selection of parameters leads to the need of complete and time-consuming adjustment of the perspective. 3D computer methods make it possible to automate the task of optimal parameters.

In order to set the optimal parameters it is recommended to use parameterization, which is a tool of up-to-date CAD software. With parameterization tools we set geometric, see Figure 2(a), and dimensional constraints, see Figure 2(b), to fulfil the conditions considered above [15,17].
By manipulating parameters ang1 – ang3, see Figure 2(c), 3(a), we obtain the set of choices of perspective pictures. The optimal variant is shown in Figure 3(b). The variants, see Figure 3(c, d), have oversized perspective. Moreover, in the variant, see Figure 3(d), the side face is poorly visible.

Figure 3. Perspective image at various parameters.

The study of other parameters of the perspective is performed based on 3D modeling. For this reason the pictures with different horizon heights and different direction of the main beam are created, see Figure 4.

Figure 4. The study of properties of the perspective image by 3D model.
3. Photorealistic rendering
Up-to-date graphical packages have advanced visualization tools. Using these tools, the perspective image takes realistic view with shadows and materials [15,17].

Sunlight is reproduced by assigning a remote source of light, which provides parallel light rays of the required direction. In the example of the construction of perspective image the direction of the light is set in parallel to the image, see Figure 5. For the shadows on the orthogonal projections the direction of the light is set on the cube diagonal, see Figure 6.

Figure 5. Photorealistic image. Figure 6. Model of a bower shadow in orthographic projections.

In addition to shadows, the image realism is achieved by specifying the materials that reproduce the image and surface quality (gloss, reflectivity, opacity, smoothness, roughness, etc.).

To increase the visibility of the perspective we can define the plane “lands” with a rectangular grid and add background and fog, see Figure 5.

The resulting image is saved in a raster format with further design rendering in Photoshop program. The study of shadows of complex objects is also carried out by the 3D model in the photorealistic rendering mode, see Figure 7.

Comparison of the effectiveness of shading complex objects using 3D techniques and traditional methods of descriptive geometry [16, 18] indicates an obvious advantage of 3D modeling. An example is the shadow of the barrier wall of the building falling on its inclined roof, see Figure 8.

Figure 7. Building model with shadows. Figure 8. Example of the study of shadows and comparison.

4. Truss node
The process is carried out in the following sequence: a dynamic block (DB) [2,4] of angles that are in the node is created; 3D node model is constructed; associative drawing of the node using 3D technology is performed. The drawings comply with the requirements [19-21].

DB is a form of storage and representation of graphic information in AutoCAD. The dynamic properties of the block are given by geometric constraints and parameters, see Figure 9(a). The example of DB for the construction of angle profile allows you to automatically build an angle in three variants, see Figure 9(b): drawing of the angle with sizes, only the outline of the angle, outline with the
axes. When the block is inserted in the drawing, the program gives you options to choose its typical sizes, see Figure 9(c) out of the available properties in the table, see Figure 9(d).

![Dynamic block](image)

**Figure 9.** Dynamic block.

When constructing 3D node model, the insertion of DB at the points B, C, D, E is implemented perpendicularly to the geometric axes of the node, see Figure 10(a). Then the node is formed by stretching out the outline of the node, see Figure 10(b), a mirror image and insertion of a batten plate are implemented, see Figure 10(c).

The drawing is made based on the 3D node model, see Figure 10(d). It is performed with the help of 3D technology. The drawing obtains associative properties that allow it to be automatically corrected when editing 3D model [15,17].

![Construction of 3D model of the truss node](image)

**Figure 10.** Construction of 3D model of the truss node.

5. **Conclusion**

Given in the paper examples show manifold opportunities of 3D modeling during the construction and analysis of models of the objects and their images.

There is a need for active and widespread implementation of 3D methods in architectural design as means of automation and optimization of the design process.
There is a need to update the educational process for Bachelor’s degree students concerning 3D modeling techniques training as an alternative to traditional methods of 2D design.

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References

[1] Volkhin K, Golovnin A, Markov V and Tokarev V 2011 Proc. of the II Int web-conf pp 280–85
[2] Asekritova S and Konstantinov A 2014 Specifics of design documentation development in production automation conditions Geometry & Graphics 1(3) pp 36–9
[3] Zubova L 2015 3D Technology in designing. Reality and prospects Retrieved from http://www.gipvn.ru/files/It-Istiriyavnerdeniya/NGN_1_2015_3y6oa.pdf
[4] BIM Revit technologies – architectural and construction design of the future Retrieved from http://genpro.ru/bim-revit
[5] 3D in architecture Retrieved from https://3d-m.ru/3d-v-arhitekture/
[6] Kheyfets A L 2013 Structural Engineering In Terms Of Densed Housing System With Allowance For Insolation 21st Int Conf in Central Europe on Computer Graphics, Visualization and Computer Vision in co-operation with EUROGRAPHICS Association (Czech Republic: University of West Bohemia) pp 25–8 Retrieved from http://wscg.zcu.cz/WSCG2013/_2013-WSCG-Poster-Proceedings.pdf
[7] Yumatova E 2017 System of Interintegrative Constructive-Analytical Problems As a Method For Forming of Future Engineers’ Professionally-Oriented Abilities Geometry & Graphics 5(2) pp 75–83
[8] Ertskina E and Korolkova N 2016 Geometric Modeling in the Automated Designing of Architectural Objects Geometry & Graphics 4(2) pp 48–54
[9] Kharakh M, Kozlova I and Slavin B 2014 Constructioning of the assembly drawing of a product by 3D method - simulations as the final stage of a study of engineering and computer graphics Geometry & Graphics 2(3) pp 36–40 Retrieved from https://naukaru.editorum.ru/en/nauka/article/6511/view
[10] Petukhova A 2015 Engineering Graphics Course Using Modern Software Systems for Students of Civil Engineering University Geometry & Graphics 3(1) pp 47–58
[11] Kheyfets A L and Vasileva V N 2015 The Course Computer Graphics for Students Building Specialties Geometry & Graphics 3(1) pp 31–9
[12] Suflyaeva N E 2014 Modern aspects of teaching graphic disciplines in technical colleges Geometry & Graphics 2(4) pp 28–33
[13] Yaroshevich O 2014 Improvement Reserves of Modern Engeneer’s Geometrical and Graphics Training Geometry & Graphics 2(2) pp 37–42
[14] Kheyfets A L 2013 Descriptive geometry course reorganization as the actual task of graphics chairs development Geometry & Graphics 1(2) pp 21–3
[15] Kheifetc A, Vasylieva V and Butorina I 2016 Computer graphics for construction workers: a Training manual for academic bachelor degree (Moscow: Yurayt) p 204
[16] Koroev Y U 2014 Descriptive geometry (Moscow: Knorus) p 422
[17] Kheifetc A, Loginovskiy A, Butorina I and Vasileva V 2015 Engineering 3D computer graphics: tutorial and workshop for academic undergraduate (Moscow: Yurayt) p 602
[18] Manakova G and Butorina I 2004 Projection of shadows (Chelyabinsk: Susu) p 33
[19] Abarinov A 1978 Preparation of detailed drawings of metal structures (Moscow: Strojisdat) p 60
[20] Georgievskiy O 2015 Construction drawings (Moscow: Arhitektura-C) p 367
[21] Korkunova N and Manakova G 2010 Drawings of details of building structures (Chelyabinsk: Susu) p 37