DIGITAL 3D VISUALIZATION IN ENGINEERING GRAPHICS EDUCATION

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ANNOTATION

This thesis examines the role of digital 3D visualization in improving the teaching and learning of engineering graphics. Traditional engineering graphics education often relies on two-dimensional drawings, which may make it difficult for students to understand complex geometric forms and their spatial relationships. Digital 3D visualization provides opportunities to represent engineering objects in an interactive and dynamic form, allowing students to rotate, enlarge, modify, and examine models from different viewpoints. Particular attention is given to the educational use of 3D models, animations, and digital design tools such as AutoCAD, SolidWorks, Fusion 360, and Blender. The thesis considers how these technologies can support the interpretation of technical drawings, improve understanding of complex structures, reduce graphical errors, and develop practical engineering skills. The use of interactive 3D visualization can also create a more engaging learning environment in which students actively explore and analyze engineering objects.

Keywords: digital visualization, 3D visualization, engineering graphics, 3D modeling, engineering education, technical drawings, geometric modeling, interactive models, digital technologies, AutoCAD, SolidWorks, Fusion 360, Blender, engineering design, practical skills.

ЦИФРОВАЯ 3D-ВИЗУАЛИЗАЦИЯ В ОБУЧЕНИИ ИНЖЕНЕРНОЙ ГРАФИКЕ

АННОТАЦИЯ

В тезисе рассматривается роль цифровой 3D-визуализации в совершенствовании преподавания и изучения инженерной графики. Традиционное обучение инженерной графике часто основывается на использовании двумерных чертежей, что может создавать определённые трудности при понимании сложных геометрических форм и их пространственных взаимосвязей. Цифровая 3D-визуализация предоставляет возможности для представления инженерных объектов в интерактивной и динамичной форме, позволяя студентам вращать, масштабировать, изменять и рассматривать модели с различных точек зрения. Особое внимание уделяется образовательному применению 3D-моделей, анимаций и цифровых средств проектирования, таких как AutoCAD, SolidWorks, Fusion 360 и Blender. Рассматривается влияние данных технологий на понимание технических чертежей, изучение сложных конструкций, снижение количества графических ошибок и развитие практических инженерных навыков. Использование интерактивной 3D-визуализации также способствует созданию более активной образовательной среды, в которой студенты самостоятельно исследуют и анализируют инженерные объекты.

Ключевые слова: цифровая визуализация, 3D-визуализация, инженерная графика, 3D-моделирование, инженерное образование, технические чертежи, геометрическое моделирование, интерактивные модели, цифровые технологии, AutoCAD, SolidWorks, Fusion 360, Blender, инженерное проектирование, практические навыки.

MUHANDISLIK GRAFIKASINI O‘QITISHDA RAQAMLI 3D VIZUALIZATSIYA

ANNOTATSIYA

Mazkur tezisda muhandislik grafikasini o‘qitish va o‘rganish jarayonini takomillashtirishda raqamli 3D vizualizatsiyaning o‘rni ko‘rib chiqiladi. Muhandislik grafikasini an’anaviy o‘qitish ko‘pincha ikki o‘lchamli chizmalardan foydalanishga asoslanadi, bu esa talabalarda murakkab geometrik shakllar va ularning fazodagi o‘zaro bog‘liqligini tushunishda muayyan qiyinchiliklarni yuzaga keltirishi mumkin. Raqamli 3D vizualizatsiya muhandislik obyektlarini interaktiv va dinamik shaklda tasvirlash imkonini berib, talabalarga modellarni aylantirish, kattalashtirish, o‘zgartirish va turli nuqtai nazarlardan ko‘rib chiqish imkoniyatini yaratadi. Tezisda 3D modellar, animatsiyalar hamda AutoCAD, SolidWorks, Fusion 360 va Blender kabi raqamli loyihalash vositalaridan ta’lim jarayonida foydalanishga alohida e’tibor qaratiladi. Ushbu texnologiyalarning texnik chizmalarni tushunish, murakkab konstruksiyalarni o‘rganish, grafik xatolarni kamaytirish va amaliy muhandislik ko‘nikmalarini rivojlantirishdagi imkoniyatlari tahlil qilinadi. Interaktiv 3D vizualizatsiyadan foydalanish talabalarning muhandislik obyektlarini mustaqil o‘rganishi va tahlil qilishi uchun faol ta’lim muhitini yaratishga ham xizmat qiladi.

Kalit so‘zlar: raqamli vizualizatsiya, 3D vizualizatsiya, muhandislik grafikasi, 3D modellashtirish, muhandislik ta’limi, texnik chizmalar, geometrik modellashtirish, interaktiv modellar, raqamli texnologiyalar, AutoCAD, SolidWorks, Fusion 360, Blender, muhandislik loyihalash, amaliy ko‘nikmalar.

INTRODUCTION

The rapid development of digital technologies is changing the way engineering knowledge is taught, represented, and applied in higher education. Modern engineering students are expected not only to understand theoretical principles but also to work confidently with digital design environments, technical drawings, three-dimensional models, and computer-aided design tools. Engineering graphics has an important role in this process because it provides students with the knowledge and practical skills required to represent, interpret, and analyze engineering objects. However, many engineering objects have complex geometric structures that can be difficult to understand when they are presented only through conventional two-dimensional drawings.

Traditional engineering graphics remains an essential component of technical education, particularly for developing skills in reading and creating technical drawings. At the same time, the increasing use of digital technologies creates opportunities to complement conventional graphical methods with interactive three-dimensional visualization. A 3D model allows students to observe an engineering object from different viewpoints, rotate and enlarge it, examine individual components, modify its geometric features, and analyze relationships between different parts. Such possibilities can make complex objects more understandable and help students establish a clearer connection between a two-dimensional technical drawing and its three-dimensional representation.

The relevance of digital 3D visualization is particularly significant for Uzbekistan, where the modernization of engineering education and the development of digitally competent engineering specialists have become important educational priorities. In 2026, the Ministry of Higher Education, Science and Innovation emphasized the need to improve the quality of engineering education, strengthen practical and innovative activities, and prepare highly qualified engineers in response to industrialization, technological development, and the digital economy.

The development of engineering education in Uzbekistan is accompanied by the establishment of new educational and technological initiatives. The launch of ToshTech University in Tashkent, for example, reflects the country's focus on modern engineering education, practical training, project-based learning, industrial cooperation, and preparation of specialists for engineering and high-technology sectors. National engineering initiatives have also increasingly included 3D modeling and other digital engineering skills. In 2026, 3D modeling was included among the competitions organized within the “Future Engineers” activities, where students demonstrated their ability to reproduce technical drawings and create three-dimensional models in AutoCAD.

There is also an existing research basis in Uzbekistan for applying computer graphics and three-dimensional modeling in higher education. Uzbek doctoral research has examined the improvement of teaching computer graphics through three-dimensional modeling and has considered visual modeling, graphic representation, and the understanding of complex objects as components of students’ graphic development. These developments demonstrate that digital visualization is already receiving attention within Uzbekistan’s engineering and educational environment. However, the educational value of 3D visualization should not be reduced to the technical ability to create digital models. Its importance lies in how these models and visualization tools are integrated into the learning process.

3D VISUALIZATION IN ENGINEERING GRAPHICS

Digital 3D visualization has become an important component of modern engineering graphics education because it provides students with a direct and interactive representation of technical objects. In traditional engineering graphics, objects are mainly represented through two-dimensional drawings, including front, top, and side views. Although these representations provide precise technical information, students may experience difficulties in mentally combining separate views into a complete image of an object, particularly when the object has complex geometric forms or internal structures. The use of three-dimensional visualization can complement conventional drawings by providing a more direct representation of the same engineering object.

2D Drawings and 3D Models: Two-dimensional technical drawings remain fundamental in engineering education because they provide standardized information about the shape, dimensions, proportions, and construction of engineering objects. Students must learn to interpret different views and understand how they correspond to the actual form of an object. However, the transition from several two-dimensional projections to a three-dimensional representation can be challenging for students who have limited experience with technical drawings. A 3D model provides an additional visual representation that can help students establish the relationship between individual drawing views and the complete object. For example, a student can compare the front, top, and side views of a component with its corresponding three-dimensional model. This comparison makes it possible to identify which lines and geometric elements in the drawing represent particular surfaces, edges, holes, or other structural features of the object.

Visualization of Engineering Objects: Three-dimensional visualization enables engineering objects to be presented in a form that more closely corresponds to their actual structure. Students can examine the external shape of a component, identify individual geometric elements, and observe how different parts are connected. This is particularly valuable when working with objects containing curved surfaces, holes, inclined planes, intersecting elements, or other complex features that may be difficult to interpret from static two-dimensional views. Digital models can also be used to demonstrate different stages of an engineering design. An object can be shown before and after modification, allowing students to observe how changes in dimensions or geometric features affect its overall structure.

Interactive Viewing and Manipulation of Models: One of the main differences between static illustrations and digital 3D visualization is the possibility of interactive manipulation. Students are not limited to observing an object from a single predetermined viewpoint. They can rotate the model, zoom in on particular elements, change the viewing angle, hide or display components, and examine the object from different directions. Such interaction allows learners to investigate the structure of an engineering object independently and repeatedly. Interactive manipulation is particularly useful for understanding relationships between visible and hidden elements. For example, rotating a model can help students determine how a hole, surface, or intersection appears from different directions. Similarly, sectioning a digital model can make internal structures visible and allow students to compare them with corresponding sectional views in technical drawings.

DIGITAL 3D VISUALIZATION TOOLS

The development of computer-aided design and three-dimensional modeling technologies has significantly expanded the possibilities for teaching engineering graphics. Digital visualization tools allow students to construct, modify, examine, and present engineering objects in a three-dimensional environment. Their educational value is particularly evident when students move between technical drawings, geometric models, and practical design tasks. The appropriate use of these tools can make engineering graphics more interactive and provide students with opportunities to develop practical skills through direct work with digital objects.

AutoCAD - AutoCAD is one of the widely used computer-aided design tools in engineering graphics education. It provides opportunities for creating accurate two-dimensional technical drawings as well as constructing and visualizing three-dimensional objects. In an educational environment, students can use AutoCAD to practice geometric construction, create technical views, develop dimensions, and construct basic 3D models. The combination of 2D drawing and 3D modeling is particularly valuable for helping students understand the relationship between a technical drawing and the corresponding engineering object. Students can create a model from given graphical information and then examine how different views represent its geometric structure.

SolidWorks - SolidWorks is a three-dimensional computer-aided design system that is widely associated with mechanical design and engineering modeling. Its educational potential is related to the possibility of creating detailed parts, combining individual components into assemblies, and generating technical drawings from 3D models. When using SolidWorks, students can study how individual geometric features contribute to the overall structure of a component. They can create sketches, apply dimensions, construct three-dimensional parts, and modify their designs according to specified requirements. Assembly functions also allow students to examine relationships between different components and understand how individual parts form a complete engineering system.

Fusion 360 - Fusion 360 provides an integrated environment for three-dimensional modeling, engineering design, and digital product development. In engineering graphics education, it can be used to introduce students to the processes of creating, modifying, and visualizing engineering components. Students can construct 3D models from sketches, apply geometric transformations, modify dimensions, and examine the resulting forms from different viewpoints. The ability to make changes to a model and immediately observe their visual consequences provides an effective way to demonstrate the relationship between geometric parameters and the final form of an engineering object.

Blender - Blender is a three-dimensional modeling, visualization, and animation platform that can also provide useful opportunities for engineering education. Although it is widely used in areas such as 3D visualization, animation, and digital content creation, its modeling and visualization capabilities can be applied to educational tasks involving the presentation of engineering objects and processes. In engineering graphics lessons, Blender can be used to create visual demonstrations of complex objects, transformations, assemblies, and technical processes. Animation can be particularly useful for showing how components move, how an assembly is constructed, or how an object changes during a particular operation.

3D Models and Animations - 3D models and animations represent an important component of digital visualization because they allow engineering objects and processes to be presented dynamically. Unlike static technical illustrations, interactive models can be rotated, enlarged, modified, and examined from different viewpoints. Students can therefore investigate the structure of an object according to their own learning needs. Animations provide another form of visualization by demonstrating movement, transformation, assembly, disassembly, and other sequential processes.

EDUCATIONAL BENEFITS OF 3D VISUALIZATION

The integration of digital 3D visualization into engineering graphics education provides a number of educational benefits that can support students in understanding technical information and developing practical engineering competencies. Three-dimensional models make it possible to present engineering objects in a more interactive and accessible form, while allowing students to examine their structure, compare different representations, and perform practical tasks in a digital environment. The educational value of 3D visualization is particularly evident in the development of students' ability to understand complex objects, interpret technical drawings, identify graphical errors, and apply theoretical knowledge in practical activities.

Understanding Complex Engineering Objects: One of the main advantages of 3D visualization is its ability to make complex engineering objects easier to understand. Some components contain multiple surfaces, holes, curved elements, inclined planes, intersections, and internal structures that may be difficult to interpret through two-dimensional drawings alone. A three-dimensional model provides students with a complete visual representation of the object and allows them to examine its individual elements in relation to the whole structure. Students can rotate the model, change its scale, and examine specific areas in greater detail. Identifying and Correcting Graphical Errors : Digital 3D visualization can also contribute to the identification and correction of graphical and modeling errors. Students can compare their digital models with technical requirements and examine whether the dimensions, geometric relationships, and structural elements correspond to the given task. For example, a student may create a model based on a technical drawing and then inspect it from different viewpoints. Incorrect dimensions, missing elements, inappropriate geometric relationships, or inconsistencies between views can become more visible during this process.

Developing Practical Engineering Skills : The educational value of 3D visualization extends beyond visual understanding. Working with digital models provides students with practical experience that is relevant to contemporary engineering activities. Students can learn to create geometric objects, modify existing models, construct assemblies, generate technical drawings, and communicate design solutions digitally. Practical tasks based on 3D visualization can also encourage problem-solving and independent learning. Students may be required to transform a 2D drawing into a 3D model, modify a component according to specific requirements, or produce technical documentation based on an existing model.

PRACTICAL APPLICATION OF 3D VISUALIZATION IN ENGINEERING GRAPHICS LESSONS

The educational effectiveness of digital 3D visualization becomes particularly evident when it is integrated into practical engineering graphics activities. Rather than using three-dimensional models only as illustrative materials, teachers can organize learning tasks in which students actively create, examine, modify, and analyze digital engineering objects. Such activities provide opportunities to connect theoretical knowledge with practical application and develop students’ ability to work with both two-dimensional drawings and three-dimensional representations.

Creating Technical Drawings from 3D Models - The reverse task can also be used in engineering graphics lessons. Students are provided with a three-dimensional digital model and are required to create the corresponding technical drawing. Depending on the learning objective, the task may include the preparation of front, top, and side views, the addition of dimensions, the use of section views, and the application of appropriate drawing conventions. This activity helps students understand that a 3D model and a technical drawing are two different representations of the same engineering object. Students must determine which views are necessary to communicate the geometry of the object accurately and how its three-dimensional form should be represented on a two-dimensional plane.

Rotating and Modifying Digital Objects - Interactive manipulation of 3D models can be incorporated into classroom activities through object rotation, scaling, and modification. Students can examine an engineering component from different viewpoints and identify how particular surfaces, holes, edges, and other features appear when the object is rotated. Teachers can also provide modification tasks in which students change specific dimensions or geometric features of an existing model. For example, students may be asked to increase the diameter of a hole, change the length of a component, add a chamfer, or modify a particular surface.

Integration of Practical Tasks into the Learning Process - For maximum educational effectiveness, these activities should be integrated systematically into the engineering graphics curriculum rather than used only as occasional demonstrations. A lesson can begin with the analysis of a conventional technical drawing, continue with the creation or examination of a 3D model, and conclude with a practical task requiring students to apply the acquired knowledge. For example, students may first analyze a set of two-dimensional views, then construct a corresponding 3D model, rotate and modify the model, examine its internal structure through a section, and finally generate a complete technical drawing.

CONCLUSION

Digital 3D visualization represents an effective and relevant tool for improving the teaching and learning of engineering graphics. The analysis presented in this thesis demonstrates that the integration of three-dimensional models, interactive visualization, and digital design environments can provide students with a clearer understanding of engineering objects and their graphical representations. By combining traditional two-dimensional technical drawings with three-dimensional models, students can more effectively understand the relationship between different views and the structure of the represented object.

The use of digital 3D visualization also creates opportunities for more active and practical learning. Students can create 3D models from technical drawings, generate drawings from digital models, rotate and modify engineering objects, examine internal structures through sections, and analyze assemblies. These activities allow theoretical knowledge to be applied through practical tasks and provide students with direct experience of digital engineering processes.

The educational benefits of 3D visualization extend to several important areas of engineering graphics education. It can facilitate the understanding of complex geometric objects, improve the interpretation of technical drawings, support the identification and correction of graphical errors, and contribute to the development of practical digital modeling and engineering skills. Interactive manipulation of models also provides immediate visual feedback, allowing students to examine their work and better understand the consequences of changes made to an object.

At the same time, 3D visualization should not be considered a replacement for fundamental engineering graphics knowledge or conventional technical drawing. Its greatest educational value is achieved when digital visualization is purposefully combined with established graphical methods, teacher guidance, and practical student activities. The effectiveness of the technology therefore depends not only on the availability of digital tools but also on the quality of their pedagogical integration into the curriculum.

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