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Cross-disciplinary model for yacht interior design: Integration of traditional visualisation and virtual reality technology

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Abstract. The aim was to investigate a cross-disciplinary model of yacht interior design in the context of the methodological integration of traditional visualisation methods and virtual and augmented reality tools. The study employed an interdisciplinary approach, systems analysis, and comparative methods, which allowed for structuring the integration of traditional visualisation and virtual reality tools, as well as identifying key interrelations between them. The study proved that the integration of traditional visualisation methods with virtual and augmented reality technologies significantly increases the efficiency of the yacht interior design process, improves the accuracy of modelling, and contributes to a better perception of the final result. It was noted that the role of traditional tools is not diminishing, but, on the contrary, is gaining new opportunities when used in conjunction with the latest arsenal of design tools. In addition, it was found that the use of a cross-disciplinary model contributes to a deeper understanding of design solutions, accelerates the processes of coordination and implementation, and expands the possibilities for optimising the functional and aesthetic characteristics of the interior. New approaches to the integration of visual aspects of design have been identified, revealing the potential of using a cross-disciplinary model for a deeper understanding and evaluation of interior design solutions. The prospect of effectively combining various visualisation tools has been outlined, which allows for improving the process of interaction between designers, engineers and customers. The current study has proposed a theoretical basis for further development and implementation of a modern approach to design that takes into account both traditional and innovative means of presenting visual information. The practical significance of the results lies in their application to yacht interior design, educational programs for specialists in marine design, architecture, and visual arts, as well as in the development of innovative approaches to the visualisation of design solutions

Keywords: ship interiors; hand sketches; VR technologies; modelling; structure of graphic images; design

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INTRODUCTION

With the rapid development of virtual reality (VR) and augmented reality (AR) technologies, cross-disciplinary approaches to yacht interior design are becoming increasingly relevant. These methods not only expand the possibilities of visualisation, but also allow for the creation of more interactive and immersive user experiences. The classic yacht interior design process now includes both traditional methods, such as sketching and creating 3D models, and the latest tools that facilitate the integration of different disciplines. This interaction is a complex but necessary process that requires the synergy of knowledge in the fields of marine architecture, engineering (computer-aided design, or CAD) and modern interior design.

Since 2014 and as of 2025, a significant amount of research has been conducted to analyse and identify the main challenges and prospects in the field of yacht interiors, as well as to adapt a cross-disciplinary design model that combines traditional methods and virtual reality technologies. This work contributes to the formation of a more integrated approach that ensures high-quality visualisation, personalisation of solutions and increased efficiency at all stages of project development. In an article by Q. Wang (2023), an analysis of user interaction with interiors designed using virtual reality tools was carried out. The work demonstrated how VR can increase user satisfaction by allowing not only to visualise space but also to communicate with it. One of the key findings of this study was that the use of virtual reality technologies not only promotes user engagement but also improves the process of understanding their advantages.

The importance of customer perception in the process of optimising methods of presenting architectural interior spaces is emphasised in the article by M. Peng *et al*. (2024), where the authors summarised that the integration of VR and AR into the yacht design process contributes to increased efficiency, accuracy and the level of emotional activity of customers, which is especially important for the premium segment. The development and structuring of these technologies combines traditional approaches and innovative visualisation tools, forming a new qualitative paradigm in the yacht industry. Scientists Y. Zhu *et al*. (2024) considered mixed reality as a tool for interior reconstruction in their study. The work presented the industrial capabilities of AR in combination with generative networks, opening up new avenues for interior renovation. The authors noted that such technologies can enhance creativity and accelerate the design process.

One of the key topics of the article by X. Liu *et al*. (2022) was the use of virtual simulation for yacht interior design. The researchers drew attention to the need to create effective, intuitive interactions inside the vessel, based on modern virtual simulation technologies. The study described in detail the methods, tools and expected benefits of using VR in yacht interior design. The study involved the development of an interactive model of a virtual yacht cabin, which focuses on user interaction with virtual space. The article by scientist L. Guo (2023) examined the use of virtual reality technology in the field of interior design, emphasising its significance and growing popularity among users. The author divided VR technology into two main categories: software and hardware, which allowed for a deeper analysis of its application in interior design. The work also emphasised that virtual reality is an interdisciplinary technology that combines various fields of knowledge, such as computer graphics, mathematics and aesthetics.

The scientific article by L. Ruggiero *et al*. (2024) examined the transformation of the yacht interior design process through the introduction of artificial intelligence (AI) technologies and their integration with traditional visualisation methods. The authors emphasised the importance of an interdisciplinary approach, which requires the coordination of knowledge from the fields of design, architecture and engineering, in the context of the growing complexity and dynamism of the modern market. The study demonstrated how AI can be a catalyst for change in the design process, allowing designers to explore alternative concepts and experiment with new forms. Continuing the theme of AI, in the scientific work of X. Li *et al*. (2025), the authors focused on how the combined use of various artificial intelligence tools can significantly improve the quality of design decisions and optimise work processes in interior design. One of the key aspects of E. Kavak's (2025) research was the ability of VR to provide immersive and interactive visualisations that allow users to "walk through" virtual interiors, which significantly improves communication quality and facilitates iterative adjustments during the design process. The author examined the technological foundations of VR, such as real-time rendering, 3D modelling, and tactile feedback. The emphasis was on the prospects for democratising design by making sophisticated visualisation tools available to a wider audience.

Although the above studies have touched on many aspects, there is a need for further research focused on structuring an approach to integrating different design methods into a single process. The aim of this study was to develop and justify a cross-disciplinary model for yacht interior design that integrates virtual reality tools and traditional methods into a single process, with an emphasis on improving the quality, efficiency and personalisation of design solutions.

At the preparatory stage, work was carried out to study existing scientific articles, publications and materials in the field of yacht interior design, virtual and augmented reality tools, as well as manual sketching techniques. Next, a comparative analysis of existing

approaches was conducted to identify the methods that would most effectively help illustrate conceptual models of yacht interiors. Their capabilities were evaluated, including methods of visualisation and interaction with space. At the stage of structuring the cross-disciplinary model, a schematic base was proposed, with the help of which a combination of traditional methods and VR/AR technology was implemented at all stages of design. The conclusion of the study included conclusions about the significance of a cross-disciplinary approach in yacht design, as well as recommendations for further research. The materials used included scientific articles, books and publications related to visual information presentation technologies, as well as demonstration materials in the form of coursework and qualification projects by students of the Design Department of the Admiral Makarov National University of Shipbuilding.

OVERVIEW OF VISUALISATION METHODS

Yacht interior design is a complex task that requires consideration of strict functional constraints, ergonomics, and high aesthetic requirements (Fablo, 2022). The current stage of technological development offers opportunities for effective interaction between traditional visualisation methods and innovative virtual and augmented reality tools. To achieve the highest quality design solutions and satisfy individual customer requests, a structured approach is needed that combines different methods and tools into a single design platform.

In the design process, any idea is realised through modelling. From sketches and drafts to accurate virtual prototypes, this stage offers an understanding of the future object from all angles (Stephens Waring Yacht Design, 2025). Designers use models to find the most suitable options, verify that the solution meets certain criteria, and communicate their concepts to the client. Some researchers have studied in detail the use of virtual reality to improve the visualisation of design data, which has significantly improved the quality of interaction with clients. A study by N. Sklyarenko (2016) found that modern technologies allow for control of the entire production process, ensuring full integration of design data. For the successful implementation of these tasks, traditional visualisation tools are widely used in practice, which form the basis for the development and visual representation of design solutions. These methods not only facilitate effective communication of ideas by designers and engineers, but also provide customers with a more complete understanding and assessment of the expected result.

In the initial stage of design, hand-drawn sketch formats are widely used (Fig. 1). As noted by Ö.S. İslamoğlu & K.O. Deger (2015), quick sketches allow designers to instantly capture their ideas and developments, experiment with shapes, spatial solutions and colour combinations without spending a lot of time. This stage serves not only as a tool for rapid prototyping, but also as a means of creative self-realisation, where each stroke reflects the individual style of the master, creating a unique visual concept. In addition, hand drawing helps to better understand the proportions and balance within the limited space of a yacht interior, which is especially important when working with small and complex objects.

Figure 1. Sketches of the interior of a motor yacht cabin (paper, watercolour, pencil)
Source: A. Tovpyga (2024)

The effectiveness of using collage techniques in presenting yacht interior design projects is due to its ability to integrate various visual elements, which contributes to the formation of a holistic and expressive image of the future space. In the context of contemporary research on visualisation and communication in design, in particular in the work of N.S. Udris-Borodavko (2018), the role of collage in the formation of a national model of graphic design in Ukraine in the 21st century is examined. The author emphasised that collages are a powerful tool for conveying conceptual ideas and emotional aspects, not only in interior design but also in graphic design, allowing the creation of multi-layered and expressive visual works. This technique of presenting information makes it possible not only to visualise aesthetic and stylistic solutions, but also

to reflect conceptual connections between materials, textures and lighting, which facilitates the perception of the project idea by customers and the design team (Fig. 2). Analysis of data collected during the study by A. Tormakhova (2019) showed that the relevance of using this expressive tool remains high in the context of introducing multimodal and interdisciplinary approaches to design processes. In the context of the modernisation and digitalisation of visual environments, collages were adapted to new formats, including digital platforms, which expanded their functionality and made them more accessible.

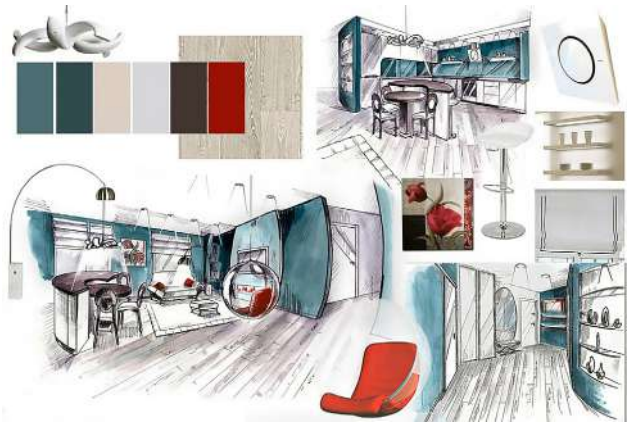

Figure 2. Collage technique for presenting an interior design
Source: T. Burlachenko (2023)

The effectiveness of presentations in demonstrating yacht interior design projects is due to their ability to provide clear and structured visual communication of the concept to various participants in the design process. This type of information presentation is a universal tool for displaying key interior elements (Fig. 3). It makes it possible to focus on the most important aspects without distracting details and complex three-dimensional images. In addition, with the development of digital technologies, presentations can be supplemented with animation effects, comments and diagrams, which significantly increases their informativeness and clarity. The relevance of using this technique remains high in the context of modern requirements for rapid information exchange and teamwork, as detailed in the work of O. Romashchenko *et al*. (2024).

The creation of physical models is the final stage of traditional design, allowing for a deeper understanding of the volume and structure of the yacht's interior. V. Turchin & O. Lugovsky (2012) noted that three-dimensional modelling using models helps to better understand the relative position of elements, the scale and proportions of space (Fig. 4). Interaction with tactile objects is particularly valuable, as it provides a tangible model of the future interior and allows for the evaluation of ergonomics and functionality. Scaled models serve as the first step towards visualising the final product in real conditions, providing the opportunity to identify shortcomings or the need for changes at the preliminary design stage.

Figure 3. Presentation of the qualification project for the design of the central interior of a motor yacht
Source: A. Kolesnyk (2024)

Figure 4. Interior layout of a motor yacht saloon
Source: D. Beleviat (2021)

The combination of hand sketches, collages, physical models, and presentations provides a flexible approach to interior design, but such methods do not fully reflect the visual, emotional, and sensory aspects of architectural space (Jin & Kim, 2017). In addition, from the point of view of interior design on yachts, traditional visualisation tools mainly focus on conveying basic design solutions, which often do not adequately reflect the complexity and diversity of specific operating conditions on a vessel. The calculation data presented in the article by F. Mauro *et al*. (2024) confirmed that in the context of this issue, it is necessary to take into

account not only standard functional parameters, but also technical characteristics related to the marine environment, such as vibration loads, the dynamic effect of waves, space limitations, and requirements for the reliability of fastening systems.

According to Y. Fan & L. Liang (2020), the use of augmented reality expands the possibilities of visualisation by superimposing information elements directly into real space. This is especially useful when designing storage systems and the location of navigation equipment, taking into account the design features of the hull. Figure 5 illustrated a simulated yacht interior in a virtual marine environment for testing individual engineering modules. This simulation helps to optimise technological solutions that minimise the use of additional volume and weight of structures by adjusting sketches (Kunkera *et al*., 2024).

Figure 5. Visualisation of the location and testing of navigation equipment and mounting systems on a motor yacht using VR technologies
Source: Beneteau (2022)

Focusing on the implementation of innovative visualisation technologies, such as virtual and augmented reality, makes it possible to model and experience interior space in conditions that are as close to real life as possible, summarised A. Hamad & B. Jia (2020). For example, the VR environment allows for the consideration of possible kinesthetic and tactile perceptions characteristic of marine conditions. In addition, interactive scenarios that simulate extreme operating conditions, such as sea waves and pitching, can be used in a virtual environment to assess the technicality and safety of fastening solutions (Fig. 6). This significantly improves the quality of design solutions, reducing the risk of errors during implementation.

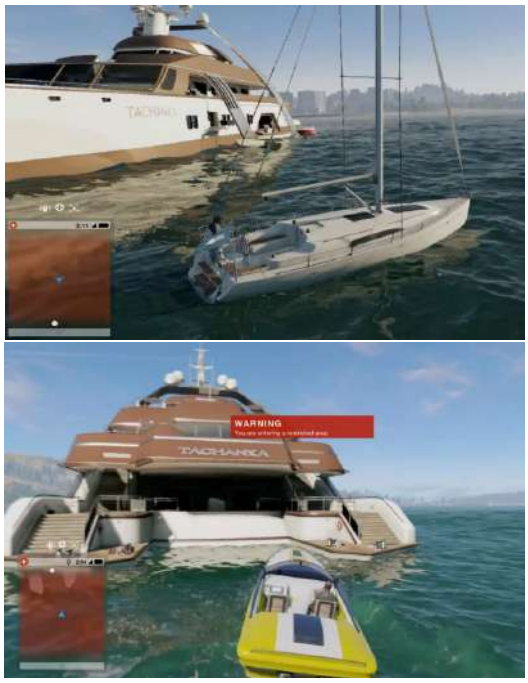

Figure 6. Simulation of yacht motion with a dynamic wave effect through virtual reality technologies
Source: image from the VR game Watch Dogs 2 (n.d.)

Changes to the spatial composition and adjustments to furniture elements and technical objects in the project are made using special devices (Zhang & Ban, 2022). This allows for real-time visualisation of proposed modifications, making the decision-making process more intuitive and collaborative. For example, designers use a tablet computer or smartphone to scan the space, after which digital models superimposed on real objects and structures are displayed on the screen (Becker *et al*., 2025; Huang & Ni, 2025). The results of work carried out by M.I. Zignego *et al*. (2022) and Y. Gui & S. Shi. (2022) showed that this allows for a more effective assessment of the accuracy of installation, verification of the compliance of design solutions with the actual dimensions and geometry of the room, and identification of possible collisions or placement errors. When discrepancies are detected and changes are necessary, the observation data can be quickly recorded, and corrections can be made manually or using specialised applications. The edits are then sent to the design team for further processing in CAD and subsequent updating of digital models. In this way, the visualisation and correction process becomes interactive and cyclical, ensuring a constant exchange of information between engineers and designers. To create panoramic images, an interactive interface with a visual range and a 360° view

is used, obtained using 3D graphics technologies and modern software services (Fig. 7). This is an additional virtual reality method that allows you to view possible options for redesigning or expanding the space using design solutions in real time and make changes to the project directly during viewing – these changes will be automatically reflected in the visualisation, which significantly increases the efficiency of the process.

Figure 7. Spherical 3D panorama of the interior of a motor yacht
Source: T. Plevako (2024)

The study by E. Brivio *et al*. (2021) examined the use of 360-degree panorama and virtual reality technologies to study the emotional state of participants, in particular their sense of presence, anxiety and emotional well-being. In the context of a cross-disciplinary model for yacht interior design, this study offered interesting parallels regarding the integration of traditional and modern visualisation methods. As part of the study of 360-degree panoramas, the authors compared two types of environments: a real panorama and a computer model. This approach made it possible to evaluate the effectiveness of different visualisation methods in creating a sense of presence – a key aspect in interior design, where the perception of space is critically important for the end user. Importantly, the study showed no significant differences between the effects of a real panoramic environment and a simulation, indicating the possibility of using 360-degree video as a more economical and simpler visualisation option. The conclusion is directly relevant to the design of yacht interiors, where it is important to implement effective and affordable visualisation methods to achieve maximum user emotional engagement. The results of the study confirm the feasibility of using 360-degree panorama technologies to create intuitive, emotionally rich spaces for users.

Special VR glasses or helmets are used for a more complete assessment of the final interior design and structural elements on site. As noted by M.Y.F. Aladin *et al*. (2024), considering the emotional and aesthetic aspects, these devices provide complete immersion of the user in a three-dimensional modelled environment with the most realistic perception of spatial solutions. This technology interacts with the digital space by tracking head movements, which helps to create a sense of presence within the virtual interior. The devices allow for dynamic viewing and navigation of the projected space in real time, assessing the volumetric and spatial structure for ergonomics and the optimal placement of furniture and structural elements. As a result, modern yacht interior visualisation practices combine a wide range of methods, from hand-drawn sketches, collages, models and presentations to advanced digital technologies based on VR/AR and 360-degree modelling. Each approach performs a separate function within the design process, contributing to the accurate communication of the concept, verification of ergonomics, adaptation to the specifics of the marine environment, and strengthening the emotional connection with the space. The combined use of these tools provides a comprehensive assessment of both the technical and visual-sensory aspects of the designed interior.

STRUCTURE OF THE CROSS-DISCIPLINARY MODEL

The effectiveness of traditional design methods combined with modern digital technologies is achieved through comprehensive integration at the stages of conceptualisation, development and finalisation of the interior. In this process, the organisation of parallel and sequential workflows plays an important role, allowing the advantages of both approaches to be utilised (Fig. 8). Balance is achieved by clearly defining the stages of work, where traditional methods are used for initial idea generation and rapid concept exchange, and digital technologies are used for detailing, analysis and final visualisation. The implementation of a sequential and cyclical process determines the effectiveness of structural interactions within the project, in which each stage complements and reinforces the next, creating an optimal symbiosis between intuitive creativity and high-precision digital processing. This approach maximises the advantages of both methodologies: the creative flexibility and efficiency of traditional methods with the precision, effectiveness and interactive analysis capabilities of modern digital solutions.

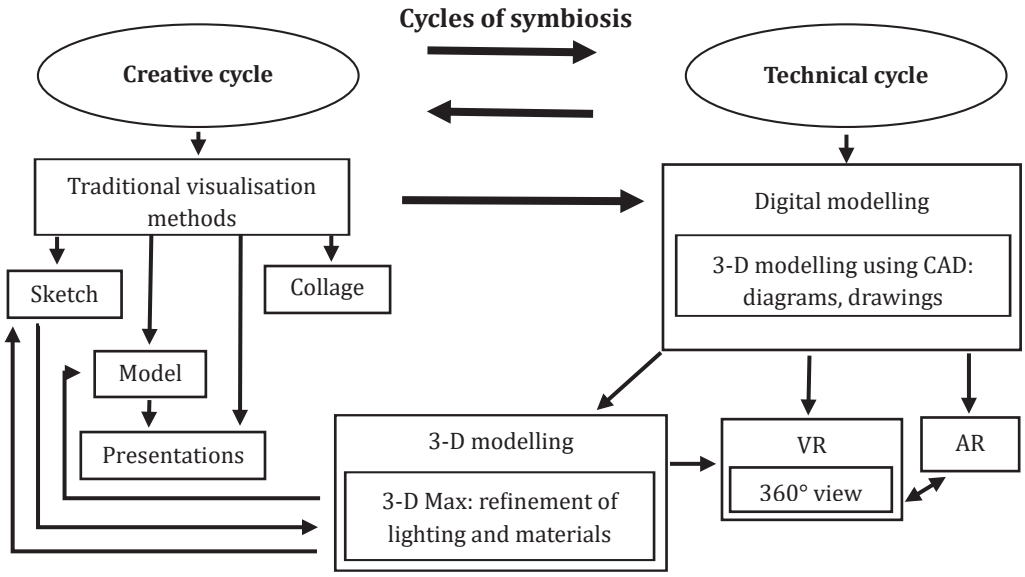

Figure 8. Project visualisation structure

Source: compiled by the authors

In the context of the proposed structure, the use of digital tools contributes to the detailed refinement and visualisation of project decisions. Thus, the process of integrating computer-aided design (CAD) and calculation systems with virtual reality (VR) tools is implemented at the stage of detailed development and digital visualisation of design concepts (Sener & Beşli, 2018). In this model, the design process is based on the sequential formation of hand sketches, based on which accurate three-dimensional digital models of the interior are created in CAD systems, including all structural, engineering and aesthetic elements. At the next stage, the interior model is exported to a VR environment using specialised converters and interfaces that preserve geometric and textural characteristics. For example, Autodesk Navisworks and 3dsMax have built-in exporters that allow models to be prepared for VR while preserving structure and materials. J. Gong *et al.* (2025) implemented a similar approach in the field of cruise ship interior design, where a three-dimensional VR model was created based on two-dimensional drawings to optimise spatial planning. Their research demonstrated improvements in key layout performance indicators, confirming the practical effectiveness of integrating VR into design processes. Specialised software for integrating computer-aided design and virtual reality systems, such as UnityReflect or UnrealDatasmith, provides automatic conversion and transfer of data from CAD environments to platforms that create virtual spaces (Uchida & Saito, 2020; Vergunova & Blinova, 2023).

The second scenario involves importing the prepared design model from CAD into 3dsMax for more accurate visualisation, final adjustment of materials, lighting and animations (Budakov, 2024). After that, the final three-dimensional scene is converted into VR formats for immersive reviews. This structure of the project model visualisation stages provides additional professional refinement of the interior using traditional tools and specialised software. During such virtual presentations, designers, engineers, and clients can make notes, make changes, and refine concepts based on both digital models and original hand-drawn sketches and physical models demonstrating stylistic and functional solutions.

At each stage of the design process, synchronisation and feedback between digital models and traditional visualisation methods, such as collages and sketches, used to adjust textures, materials and colour schemes must be ensured. This approach ensures that changes made to the digital model remain faithful to the original aesthetic concept laid out in the hand-drawn sketches and contributes to a more accurate match between the final project and the designer's vision. Thus, the combined use of traditional visualisation methods and modern virtual reality technologies creates an effective dialogue between the concepts developed and their practical implementation. Such cross-disciplinary synthesis increases the accuracy of design solutions, helps to prevent possible errors and significantly increases the level of customer confidence and satisfaction. The result was a harmonious combination of aesthetics, engineering reliability and operational safety, which is especially important in the context of shipbuilding.

CONCLUSIONS

As part of the study, a conceptual model for integrating traditional visualisation methods and virtual reality technologies into the process of designing yacht interiors was proposed. This interconnection is based on the synthesis of classical approaches to visualisation, such as manual sketching, collage techniques and mockup

modelling, with innovative immersive technologies that provide highly accurate and interactive information exchange. The similar formation of structural interrelationships at the stage of interior visualisation involves increasing the efficiency of design procedures, ensuring a more accurate perception of spatial solutions and stimulating interdisciplinary interaction between designers, engineers and end users in the context of complex modelling of yacht interiors.

The functional symbiosis of classic techniques and immersive VR and AR tools forms a competent approach to the use of various methods of presenting visual information and allows not only to enhance the creative potential of designers, but also to significantly increase the accuracy, efficiency and quality of design solutions. In the context of yacht interior design, a set of tasks aimed at developing a methodology for integrating traditional and virtual visualisation techniques includes in-depth research into the possibilities of automating data synchronisation processes between different modelling platforms. Of particular relevance is the creation of adaptive tools that ensure "seamless" interaction and information exchange between classic hand sketches, yacht interior design layouts, digital CAD models, and virtual environments. It is advisable to focus on the development of VR and AR user interfaces that ensure the convenience of interaction between specialists of various profiles with digital models.

Prospects for further research in this area are related to the improvement of classic visualisation techniques, the expansion of the functional capabilities of virtual reality, and the combination of the above-mentioned means of presenting information with other innovative technologies. For example, the development of digital twins in interiors, augmented reality based on spatial scanning, and methods of introducing artificial intelligence into the process. These areas open up new horizons for scientific research and contribute to the creation of integrated technological solutions and the expansion of opportunities for the effective design of yacht interiors.

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CONFLICT OF INTEREST

None.

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Крос-дисциплінарна модель проєктування яхтового інтер'єру: інтеграція традиційної візуалізації та технології віртуальної реальності

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Анотація. Метою було дослідити крос-дисциплінарну модель проєктування яхтового інтер'єру в контексті структури методологічної інтеграції традиційних методів візуалізації та засобів віртуальної і доповненої реальності. У дослідженні застосовано міждисциплінарний підхід, системно-аналітичний та компаративний методи, що дозволило структурувати інтеграцію традиційної візуалізації та віртуальної реальності й виявити ключові зв'язки між ними. Дослідженням доведено, що інтеграція традиційних методів візуалізації з технологіями віртуальної і доповненої реальності істотно підвищує ефективність процесу проєктування інтер'єрів яхт, покращує точність моделювання і сприяє більш якісному сприйняттю кінцевого результату. Зазначено, що роль традиційних інструментів не зменшується, а, навпаки, отримує нові можливості, при одночасному застосуванні разом з новітнім арсеналом засобів проєктування. Крім того, було виявлено, що використання крос-дисциплінарної моделі сприяє більш глибокому розумінню проєктних рішень, прискорює процеси узгодження і реалізації, а також розширює можливості оптимізації функціональних і естетичних характеристик інтер'єру. Виявлено нові підходи до інтеграції візуальних аспектів проєктування, що розкривають потенціал використання крос-дисциплінарної моделі для більш глибокого розуміння і оцінки інтер'єрних рішень. Окреслено перспективу ефективного поєднання різних інструментів візуалізації, що дозволяє поліпшити процес взаємодії між дизайнерами, інженерами та замовниками. Поточне дослідження запропонувало теоретичну основу для подальших розробок і впровадження сучасного підходу до проєктування, що враховує як традиційні, так і інноваційні засоби представлення візуальної інформації. Практична цінність отриманих результатів полягає в їх застосуванні у проєктуванні інтер'єрів яхт, у навчальних програмах підготовки фахівців у сфері морського дизайну, архітектури та візуальних мистецтв, а також у розробці інноваційних підходів до візуалізації проєктних рішень

Ключові слова: суднові приміщення; ручні ескізи; VR-технології; макетування; структура графічних зображень; дизайн