3D ANATOMY VISUALIZATION AND SIMULATION IN MEDICAL PRACTICE: TECHNOLOGICAL FRAMEWORK AND NATIONAL ADAPTATION

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Annotation. *The paper explores the scientific and technological foundations of three-dimensional (3D) anatomy visualization and simulation in modern medical practice. It focuses on the full cycle of medical data processing—from DICOM-based imaging and segmentation to 3D modeling, visualization, and interactive simulation. The study also proposes a national adaptation framework for implementing 3D medical technologies in healthcare and education systems, considering resource constraints, ethical aspects, and digital infrastructure development.*

Keywords. *3D visualization, medical simulation, DICOM, segmentation, anatomical modeling, national adaptation, medical education, telemedicine*

Аннотация. *В статье рассматриваются научно-методические и технологические основы трёхмерной (3D) визуализации и моделирования анатомии человека в медицинской практике. Описывается полный цикл обработки медицинских данных — от получения изображений в формате DICOM и сегментации до построения трёхмерных моделей, визуализации и интерактивной симуляции. Кроме того, предлагается национальная стратегия адаптации для внедрения 3D-технологий в систему здравоохранения и медицинского образования с учётом ограниченных ресурсов, этических норм и развития цифровой инфраструктуры.*

Ключевые слова. *3D-визуализация, медицинская симуляция, DICOM, сегментация, анатомическое моделирование, национальная адаптация, медицинское образование, телемедицина*

The development of innovative 3D visualization technologies in medicine is transforming traditional approaches to anatomical analysis, diagnostics, and clinical simulation. This paper presents a comprehensive methodology for creating an interactive 3D anatomy simulator that integrates computer graphics, digital imaging, and virtual environments. The proposed framework addresses the need for localized, cost-effective, and technologically advanced visualization tools suitable for Uzbekistan's medical context.

The system architecture is based on the combination of DICOM data processing, 3D model reconstruction, and interactive visualization. Medical imaging data from CT and MRI scans are processed in 3D Slicer using segmentation algorithms to isolate anatomical structures with high precision. The resulting models are refined and textured in Blender, while Unity and Unreal Engine provide a dynamic environment for real-time interaction. Users can manipulate the models—rotate, dissect, zoom, and analyze internal organs—through virtual (VR) and augmented reality (AR) interfaces.

A central element of the simulator is the integration of the Orthanc DICOM server, which allows secure management and streaming of radiological data. This connection bridges real diagnostic information with educational and clinical simulations. Furthermore, the development of a WebGL-based online version ensures accessibility without additional installations, enabling remote use for students, doctors, and researchers.

The study also analyzes global analogs such as Visible Body, Anatomage Table, and 3D4Medical, emphasizing their technological sophistication but limited localization and high licensing costs. The proposed approach, in contrast, focuses on the development of a national 3D simulator with an Uzbek-language interface and adaptation to local medical standards.

This initiative lays the foundation for a new stage in digital healthcare transformation, enhancing anatomical visualization, supporting surgical planning, and improving the quality of clinical training. Future research directions include the integration of artificial intelligence for automatic segmentation and the

expansion of VR/AR-based diagnostic simulations. Three-dimensional (3D) visualization and simulation technologies have become a crucial component of modern medical practice, offering unprecedented opportunities for precision diagnosis, surgical planning, and medical education. By converting medical imaging data into interactive 3D anatomical models, healthcare professionals can better understand complex spatial relationships and improve decision-making accuracy.

For developing healthcare systems, the national adaptation of such technologies requires a balanced approach—combining open-source tools, local expertise development, and adherence to international standards for data privacy and interoperability. When properly implemented, 3D anatomy visualization can enhance surgical outcomes, accelerate training, and promote equitable access to advanced medical technologies across all regions.

References

1. Aldridge R. D. (2022). 3D Visualization in Medical Practice: Applications and Outcomes. Journal of Medical Simulation.

2. Pieper S., Lorensen, B., Schroeder, W. (2020). 3D Slicer: A Platform for Biomedical Research and Visualization. Insight Journal.

3. Epic Games. (2022). Unreal Engine for Scientific Visualization. Technical Report.

4. Unity Technologies. (2023). Unity Engine for Medical Simulation and VR Training. Whitepaper.

5. 3D4Medical Ltd. (2023). Complete Anatomy: Educational Software Manual. Dublin.

6. Mahmudova M. A. (2025). Innovative Methodology for Creating 3D Anatomical Simulators in Uzbekistan. Tashkent.