

COMPUTER GRAPHICS-BASED SYSTEM FOR VISUAL DIAGNOSIS OF MEDICAL DATA

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Abstract: *The increasing volume and complexity of medical imaging data from CT, MRI, and PET pose challenges for accurate and efficient diagnosis. This study presents an integrated visual diagnostic system based on computer graphics principles. The system consists of three modules: data processing for image standardization and segmentation, visualization for interactive 2D/3D modeling using the Marching Cubes algorithm, and an interactive communication module supporting VR/AR interfaces. The system was evaluated on 450 retrospective images from public (TCIA) and local datasets focusing on breast and liver pathologies. The results showed a tumor detection precision of 93.5% and sensitivity of 90.8%. A user study involving ten clinicians demonstrated a 40% reduction in diagnostic time and confirmed the system's effectiveness in understanding complex anatomical relationships, particularly for surgical planning. The findings indicate that computer graphics-based visual diagnostic systems can significantly enhance diagnostic accuracy, efficiency, and clinical communication.*

Keywords: *Medical Imaging, 3D Visualization, Computer-Aided Diagnosis, Image Segmentation, Clinical Decision Support, Augmented Reality, Digital Diagnostics, Human-Computer Interaction, Diagnostic Accuracy, Visual Analytics*

INTRODUCTION

Modern medical diagnostics is a fundamental stage of any treatment process. The accuracy of diagnostic decisions directly affects the patient's health and life. In recent decades, significant achievements have been recorded in medical imaging technologies. Methods such as computed tomography (CT), magnetic resonance imaging (MRI), positron emission tomography (PET), and digital radiography have enabled the collection of vast amounts of data about the internal structure and physiological processes of the human body. However, this complex and multidimensional flow of data has also created new challenges for specialists. These include the necessity to interpret a very large volume of images in a short time, the possibility of subjective assessment errors, and the difficulty of identifying hidden correlations not visible to the naked eye.

Computer graphics and visualization sciences can play a decisive role in solving these problems. Computer graphics is a field that enables the transformation of digital data into a visual, intuitively understandable form, allowing for its manipulation and in-depth analysis. This article illuminates the principles, capabilities, and clinical significance of an integrated visual diagnosis system built on computer graphics. The system should not only visualize data but also have the capability to process it intelligently, highlight important signs, and even provide preliminary analytical conclusions. The main goal of the research is to establish the principles for developing an interactive platform that ensures effective collaboration between the physician and technology, improves diagnostic accuracy and speed, and to evaluate its practical impact.

Methods

The research project involves a two-stage approach: developing the architectural solution for the system and experimentally evaluating it based on clinical data. The system architecture is divided into three main logical modules: data processing and preparation, visualization and analysis, and interactive communication and decision support.

In the data processing stage, images from various sources (CT, MRI, PET, etc.) are standardized. This stage involves noise reduction, contrast enhancement, artifact removal, and spatial alignment (registration) of images from different modalities. Segmentation, the process of delineating various anatomical structures or pathological foci in an image, is the most critical part of this system. For this purpose, both traditional computer graphics algorithms (e.g., edge detection, region growing) and modern deep learning-based convolutional neural networks are integrated.

The visualization module is focused on creating two- and three-dimensional (2D and 3D) images. Using classical computer graphics algorithms such as Marching Cubes and ray tracing, a true three-dimensional model is created from a set of two-dimensional slices. The ability to rotate this model in any direction, obtain virtual slices, change transparency levels, or color-code specific structures provides the radiologist with the opportunity to examine the pathology from all angles.

The interactive communication module is the interface that allows the physician to control these powerful visual tools. This may involve not only a mouse or touch screen but also virtual and augmented reality (VR/AR) devices. The physician can "travel" inside the 3D model, examine automatically detected suspicious areas, and accurately measure their volume and density.

For evaluation, two datasets were used retrospectively: 300 tomographic breast tumor images obtained from the open-source TCIA (The Cancer Imaging Archive) database, and 150 MRI images related to liver pathologies (hepatoma, hypervascular tumors) obtained from a local center. The system's performance was evaluated based on precision, sensitivity (recall), and F1-score metrics. Additionally, a group

consisting of five experienced radiologists and five general practitioners was asked to test the system and complete a questionnaire about their user experience.



Figure 1. Interactive virtual reality–based interface for exploring 3D reconstructed medical images, enabling real-time analysis and clinical decision support.

Results:

The developed visual diagnostic system demonstrated high efficiency in processing image data and 3D modeling. The average precision for tumor detection was 93.5 percent, and sensitivity was 90.8 percent, which is a significantly higher indicator compared to viewing pure 2D images. The segmentation process lasted an average of 3 to 8 minutes, indicating the system's capability to operate in near real-time.

In terms of time savings, the results were even more convincing. Using the system, radiologists spent on average nearly 40 percent less time identifying and characterizing tumors (location, size, relationship with surrounding tissues). This is particularly important in emergency situations or during large-scale screening work.

The results of the user survey confirmed the system's high practical value. Most specialists (90 percent) emphasized that 3D visualization significantly facilitates understanding anatomical relationships. The ability to view the model from any angle and obtain virtual slices was especially valued in surgical planning. Some participants (mainly older physicians less accustomed to digital technologies) initially commented on the complexity of the interface, but after brief practice, they also found the system convenient to work with.

Discussion

The obtained results clearly demonstrate the potential of computer graphics to revolutionize medical diagnostics. When reviewing traditional 2D images, the radiologist's brain must mentally combine hundreds, even thousands, of individual slices to form a three-dimensional conception. This not only increases cognitive load but also raises the probability of error. The visual diagnosis system takes on this load and provides an accurate, measurable, and manipulable 3D model in its place. This allows the physician to focus their attention directly on their primary task: diagnosing and evaluating the pathology.

The high accuracy of segmentation is the system's most important advantage, and the synergy between traditional graphics algorithms and artificial intelligence played a decisive role in achieving this result. The AI model performs the initial "rough" segmentation, and the physician can then fine-tune the result using traditional graphic tools. This approach provides an optimal balance between full automation and full manual control.

It should also be noted that the system's benefits are not limited to speed and accuracy. It is also an excellent tool for education and training.

Medical students or physicians in specialization can study complex pathologies in a safe environment by working with virtual anatomical models.

Furthermore, the system improves communication between the physician and the patient. The patient can see their disease in a clear 3D model, understand it, and become more actively involved in the treatment plan.

However, limitations also exist. Powerful computing resources (high-level processors, graphics cards) are required for the system to function fully effectively. Developing and configuring the software is very costly.

Most importantly, the system can never fully replace the physician. It is only a tool; the final decision always remains with the human specialist. Also, not all types of pathologies (e.g., diffuse inflammatory processes) may currently be too complex for high-accuracy modeling.

Future work can proceed in several directions. First, increasing the speed of operation for real-time performance.

Second, training artificial intelligence models to be more precise and multi-branch, developing specialized segmentation tools for different organ systems and diseases.

Third, deepening integration with virtual reality, providing the physician with the opportunity to work with the 3D model in a state of full "immersion."

Conclusion

The computer graphics-based visual diagnostic system is on its way to becoming an important component of modern medicine.

It not only speeds up the diagnostic process and reduces errors but also provides the physician with the opportunity to understand pathology in a completely new, deeper way.

The research results show the system's high technical performance indicators and its positive reception by clinicians.

In the era of digital transformation, developing and implementing such technologies is not only a scientific achievement but also a primary task in providing patients with quality and effective medical care.

The future is built on the convergence of medical and technical sciences, the harmonious collaboration of artificial intelligence and human expertise, and visual diagnostic systems are destined to be an integral part of this future.

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