Published Online: 2026 February 3 Letter

The Potential of Gesture Recognition Technology in Transforming Medical Education: Navigating Challenges and Future Directions

Zohreh Khoshgoftar [1], Samane Babaei [2,*], Mahmoud Mansouri [1], Seyedeh Maedeh Rezapour [1]

[1] Department of Medical Education, School of Medical Education and learning technologies, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[2] Student Research Committee, Department of Medical Education, School of Medical Education and Learning Technologies, Shahid Beheshti University of Medical Sciences, Tehran, Iran

[*] ***Corresponding Author:*** Student Research Committee, Department of Medical Education, School of Medical Education and Learning Technologies, Shahid Beheshti University of Medical Sciences, Tehran, Iran. Email: s.babaei7203@yahoo.com

Received: 24 September, 2025; **Revised:** 22 November, 2025; **Accepted:** 22 November, 2025

Keywords: Recognition Technologies, Gestures, Nonverbal Communication, Medical Education

Dear Editor,

The digital era has fundamentally altered paradigms in health sciences and education (1). As medical education evolves to meet advancing technology and changing healthcare needs, innovative teaching methods have become critical. Technology is now a key factor in transforming clinical training, moving beyond outdated "see one, do one, teach one" models. gesture recognition technology (GRT) is one such innovation poised to significantly impact clinical education. GRT refers to a system's ability to interpret human gestures via mathematical algorithms. It enhances non-verbal communication, allowing teachers to use gestures to complement verbal instructions, thereby activating multi-sensory channels to improve teaching effectiveness and student engagement. The technology relies on advanced algorithms, such as deep convolutional neural networks, to accurately interpret gestures. In medical education, GRT facilitates interaction with virtual simulations, providing an engaging, practical learning experience. It allows learners to refine clinical skills through realistic practice with immediate feedback, effectively bridging the gap between theoretical knowledge and practical application (2). This commentary explores the transformative potential of GRT in medical education by examining its pedagogical foundations, diverse applications, and cutting-edge advancements. It aims to delineate the advantages and challenges — such as cost and integration — faced during implementation, while also proposing potential solutions and exploring promising future directions. Furthermore, it provides a focused perspective on the status and infrastructural requirements of GRT within the context of Iranian medical schools. This localized analysis aims to contribute a practical dimension to the global conversation, offering insights that can help navigate the adoption of this innovative technology in varied educational landscapes.

Applications of Gesture Recognition Technology in Medical Education

Gesture recognition technology serves as a new paradigm in medical education, improving students' skills and their understanding of clinical processes through interactive, visual experiences.

- Application in Anatomical Education: GRT has profound applications in anatomical education. By leveraging natural similarities between the human hand and anatomical structures, it provides a tangible, intuitive approach to understanding complex relationships. For example, gestures can visualize bone structures and joint movements, reinforcing the link between anatomical knowledge and clinical practice. Instructors can use gestures to separate anatomical layers while providing verbal explanations, enabling effective and rapid training (2).

- Application in Medical Image Interpretation: New gesture-based methods allow for sterile manipulation of medical images in the operating room, supporting a doctor's focus and providing fast response times. GRT can transform clinical training for image interpretation by enabling contactless interaction. Students can review

How to Cite: Khoshgoftar Z, Babaei S, Mansouri M, Rezapour SM. The Potential of Gesture Recognition Technology in Transforming Medical Education: Navigating Challenges and Future Directions. J Med Edu. 2026;25(1):e166625. doi: https://doi.org/10.5812/jme-166625

radiological images in real-time using hand gestures (e.g., zooming), while instructors analyze their movements via a tracking system to provide precise feedback on interpretation accuracy (3).

• Application in Surgical Education: GRT is highly useful for teaching surgical procedures, where precise hand-eye coordination and spatial understanding are crucial. By mimicking surgical movements with hand gestures, students can better grasp procedural steps and technical nuances before clinical exposure. In surgical simulation, GRT tracks novice surgeons' hand movements in virtual environments (e.g., laparoscopy) and provides real-time feedback on accuracy, speed, and movement angles. The system can also interpret a surgeon's hand movements to facilitate smoother communication with a robotic assistant (4). Gesture recognition technology is also used in medical assistant robots to deliver instruments via gesture commands, making the surgical process more efficient and reducing the need for verbal commands.

Cutting-edge Gesture Recognition Technologies in Clinical Training

1. A virtual surgical prototype system for maxillofacial surgery uses GRT to create an immersive training environment. Trainees perform virtual procedures like incision operations using hand gestures recognized in real-time, simulating authentic surgery without physical instruments. Integration with collision detection and biomechanical modeling enhances realism, significantly improving training efficiency and effectiveness in a safe, controlled setting (5).

2. In hand-assisted laparoscopic surgery (HALS), a surgeon's hand inside the workspace restricts the use of an additional tool. A proposed solution is a two-arm surgical robot assistant. One arm orients the endoscope, while the other handles a tool. The surgeon controls the robot's collaborative movements, such as holding tissue or pointing to focus the camera, through intuitive gestures (6).

3. "Gestix" is a vision-based hand gesture system for navigating medical images. It translates gestures into commands based on their temporal trajectories. Tested during a brain biopsy training, this interface helped maintain the surgeon's focus, enabling rapid, intuitive reactions and easy interaction, demonstrating GRT's potential for immersive clinical training (3).

Advantages, Challenges, and Solutions

GRT in clinical education offers significant advantages. It fosters enhanced interactivity, allowing hands-on practice in a safe, virtual environment. Real-time feedback enables immediate skill refinement, and it supports the acquisition of crucial fine motor skills and hand-eye coordination (7). Training programs are customizable, adapting to individual learning paces. GRT also facilitates objective, data-driven assessments and expands access to training through remote learning capabilities. It aids in developing non-verbal communication skills by tracking gestures during patient interactions and encourages collaboration among students and instructors.

However, challenges exist. Technical limitations can affect accuracy in complex environments. Continuous Research and Development (R&D) to improve algorithms and regular maintenance are key solutions. Curriculum integration can be difficult; collaboration between educators and developers is needed to create tailored modules. The high cost of implementation can be alleviated through partnerships, grants, or exploring lower-cost alternatives. User resistance requires comprehensive training and faculty development. Privacy and data security concerns must be addressed with robust protection measures and compliance with regulations such as the health insurance portability and accountability act (HIPAA). Over-reliance on technology is a risk; a balanced approach that includes traditional methods is essential. Accessibility is a hurdle for underfunded institutions, which can be mitigated by forming consortia to share resources and expertise. Variability in user experience necessitates tiered training programs and ongoing support. Cultural differences in non-verbal communication can lead to misunderstandings, requiring the development of culturally adaptive algorithms. Finally, the need for ongoing maintenance can strain resources; partnerships with technology providers and training staff for basic troubleshooting can help.

Status of Gesture Recognition Technology in Medical Education in Iran

The adoption of GRT in Iranian medical education is currently in its nascent stages, characterized by growing academic interest and pioneering research initiatives. Several major medical universities and research centers, particularly in Tehran and Shiraz, have begun exploring GRT within the scope of virtual simulation and surgical training laboratories. However, widespread implementation remains limited. The primary focus has been on theoretical research and small-scale prototypes, often developed in university settings, with a noticeable gap between research output and integration into standardized curricula. Challenges such as international sanctions, which can restrict access to high-end hardware and specialized software, and limited dedicated funding have slowed its progression. Despite these hurdles, the recognized potential of GRT to enhance medical training is driving a slow but steady increase in collaborative projects between Iranian computer science and medical departments, signaling a promising, albeit cautious, trajectory toward future adoption.

Infrastructure Required for Gesture Recognition Technology in Iranian Medical Schools

The successful integration of GRT into Iranian medical schools requires a multi-faceted infrastructural foundation. Firstly, robust technical infrastructure is paramount, including high-performance computing resources, low-latency data networks, and modern GRT hardware (e.g., depth-sensing cameras, sensors). Secondly, specialized software for simulation, data analysis, and curriculum management is needed, which could be developed through in-house R&D or adapted from open-source platforms to circumvent licensing barriers. Thirdly, human resource development is critical; this involves training faculty to become proficient with the technology and creating technical support teams for system maintenance. Fourthly, a clear policy and regulatory framework must be established to address data privacy, ethical use, and accreditation standards for GRT-based training modules. Finally, securing sustainable funding through government initiatives, university budgets, and public-private partnerships is essential to overcome initial setup costs and ensure long-term viability. A phased implementation plan, starting with pilot centers of excellence, could serve as a practical model for nationwide rollout.

Future Directions of Gesture Recognition Technology in Medical Education

The future of GRT in medical education is promising. Key developments include highly realistic virtual environments that simulate complex clinical scenarios. Integration with Artificial Intelligence (AI) will lead to adaptive learning systems that analyze student performance in real-time, providing personalized feedback and tailored training programs. This technology will expand into interdisciplinary applications, fostering innovation in surgical tools and rehabilitation devices. As remote education grows, AI-powered GRT will facilitate highly responsive interactive learning for distributed students. It will extend to telemedicine, allowing professionals to conduct nuanced virtual assessments through intuitive gestures. AI-driven, culturally adaptive algorithms will dynamically interpret non-verbal communication differences, preparing students for global patient populations. Integration with wearable technology will enable intelligent real-time monitoring and personalized feedback during simulations. AI can also enhance engagement through adaptive gamification, tailoring challenges to individual progression. Machine learning and predictive analytics will be crucial for evaluating educational impact and identifying best practices. Finally, AI will help develop implementation standards to ensure consistent quality. By leveraging these avenues, GRT can transform medical education, equipping future professionals with the advanced skills needed for modern healthcare.

Conclusions

Gesture Recognition Technology represents a paradigm shift in medical education, moving decisively beyond passive observation. Grounded in experiential and social cognitive learning theories, it enables immersive simulation where students safely practice and refine essential clinical skills — from anatomy to surgery — while receiving crucial real-time feedback. While challenges like cost and integration remain, advancements in AI, wearables, and adaptive algorithms promise more personalized and effective training. Embracing this technology is essential for equipping future healthcare professionals with the sophisticated skills demanded by modern, technology-driven practice.

Footnotes

AI Use Disclosure: The authors declare that no generative AI tools were used in the creation of this article.

Authors' Contribution: Z. Kh. and S. B. have made substantial contributions to the conception or design of the work. Z. Kh., S. B., M. M., and M. R. have made substantial contributions to drafting the work or reviewing it critically for important intellectual content; have given final approval of the version to be published; and have agreed to be accountable for all aspects of the work.

Conflict of Interests Statement: The authors declare no conflict of interests.

Funding/Support: The authors declare that there was no funding for the study.

References

1. Khoshgoftar Z, Karimi Rouzbahani A. Medical Education AI-Based. *Global Medical Education in Normal and Challenging Times*. 2024. p. 259-65. https://doi.org/10.1007/978-3-031-51244-5_28.
2. Karambakhsh A, Kamel A, Sheng B, Li P, Yang P, Feng DD. Deep gesture interaction for augmented anatomy learning. *Int J Inf Manage*. 2019;**45**:328-36. https://doi.org/10.1016/j.ijinfomgt.2018.03.004.

3. Wachs JP, Stern HI, Edan Y, Gillam M, Handler J, Feied C, et al. A gesture-based tool for sterile browsing of radiology images. *J Am Med Inform Assoc*. 2008;**15**(3):321-3. [PubMed ID: 18451034]. [PubMed Central ID: PMC2410001]. https://doi.org/10.1197/jamia.M241.
4. Wang W, He M, Wang X, Ma J, Song H. Medical gesture recognition method based on improved lightweight network. *Applied Sci*. 2022;**12**(13):6414. https://doi.org/10.3390/app12136414.
5. Zhao H, Cheng M, Huang J, Li M, Cheng H, Tian K, et al. A virtual surgical prototype system based on gesture recognition for virtual surgical training in maxillofacial surgery. *Int J Comput Assist Radiol Surg*. 2023;**18**(5):909-19. [PubMed ID: 36418763]. [PubMed Central ID: PMC10113313]. https://doi.org/10.1007/s11548-022-02790-1.
6. Lopez-Casado C, Bauzano E, Rivas-Blanco I, Perez-Del-Pulgar CJ, Munoz VF. A Gesture Recognition Algorithm for Hand-Assisted Laparoscopic Surgery. *Sensors (Basel)*. 2019;**19**(23). [PubMed ID: 31779237]. [PubMed Central ID: PMC6929113]. https://doi.org/10.3390/s19235182.
7. Babaei S, Toofaninejad E, Kalantarion M, Taghirad HD, Mohammadi SF. From touch to skill: How tactile feedback is transforming simulation-based medical education? *Med Teach*. 2025;**47**(2):370. [PubMed ID: 39405401]. https://doi.org/10.1080/0142159X.2024.2415497.