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ChatGPT and DeepSeek in Bioinformatics: Revolutionizing Research, Education, and Clinical Applications

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ABSTRACT:

The integration of large language models (LLMs), particularly ChatGPT, in bioinformatics is transforming the landscape of medical research, clinical decision-making and biomedical education. This paper explores the multifaceted roles that ChatGPT plays in bioinformatics, from accelerating drug discovery to enhancing diagnostic accuracy and medical education. Through its natural language processing capabilities, ChatGPT helps researchers navigate complex biological data, predict protein structures, and analyze genetic information with unprecedented speed and accuracy. Additionally, it fosters collaboration and communication among scientific communities by generating hypothesis-driven research, streamlining workflows, and making scientific literature more accessible. Despite its tremendous potential, the widespread use of AI in bioinformatics also raises ethical concerns such as biases in data, data privacy issues, and misinformation propagation. This manuscript provides a detailed review of ChatGPT's applications, challenges, and future implications in bioinformatics, shedding light on its transformative power while also acknowledging the inherent risks of its deployment.

1. Introduction :

In recent years, artificial intelligence (AI) has emerged as a powerful tool across various domains, with bioinformatics being one of the most prominent fields where it has shown transformative potential. Bioinformatics deals with large-scale biological data analysis, including genomic sequences, protein structures, and clinical data. The use of machine learning (ML), deep learning (DL), and natural language processing (NLP) technologies has accelerated progress in understanding complex biological phenomena, and at the forefront of this revolution is ChatGPT, a large language model developed by OpenAI. ChatGPT, built on cutting-edge neural network architectures such as GPT (Generative Pretrained Transformer), has exhibited remarkable capabilities in text generation, data interpretation, and even conversational exchanges. Its implementation in bioinformatics can lead to faster, more efficient research, and more effective clinical decision-making. From assisting in genomics to improving medical education and enhancing drug discovery, ChatGPT is changing the way bioinformaticians and healthcare professionals approach complex problems.

However, as with any technological advancement, there are challenges to consider. These include questions of data privacy, ethical implications of AI-generated content, and the reliability of AI models in clinical decision-making. This manuscript seeks to explore the potential and limitations of ChatGPT in bioinformatics, providing an overview of its applications, ethical considerations, and the future directions of AI in biomedical sciences.

2. The Role of ChatGPT and DeepSeek in Bioinformatics

Bioinformatics is a highly data-driven discipline, and the sheer volume and complexity of the data pose significant challenges. AI models like ChatGPT are uniquely positioned to enhance data processing, streamline research workflows, and provide novel insights across a range of bioinformatic applications. Below, we explore several domains where ChatGPT's capabilities have been particularly impactful.

The emergence of DeepSeek as a multimodal AI model has sparked a paradigm shift in scientific discovery, research, and healthcare, rivaling established models like ChatGPT. Researchers have highlighted its potential in autonomous content generation and innovation in various fields (Kayaalp et al., 2025). DeepSeek's rapid development and open accessibility have excited the global scientific community, challenging AI dominance and fostering new collaborations (Gibney, 2025a).

China's strategic investment in AI has played a crucial role in its rise, positioning DeepSeek as a disruptive force in the field (Conroy & Mallapaty, 2025). However, while scientists are increasingly adopting DeepSeek for research applications (Gibney, 2025b), critical challenges remain, particularly in healthcare, where AI integration still faces significant gaps (Peng et al., 2025). As AI technology advances, further research and regulatory frameworks will be essential to harness its full potential while addressing ethical and practical concerns.

Genomic Data Analysis

Genomic data analysis is one of the most promising applications of AI in bioinformatics. With the advent of next-generation sequencing (NGS) technologies, massive datasets containing genetic sequences are being generated daily. ChatGPT integrated with bioinformatics tools and databases,

can assist in various genomic analysis tasks, including sequence alignment, variant calling, and functional annotation. ChatGPT aids in annotating large genomic datasets by associating gene sequences with known functional elements, regulatory regions, and potential disease-related mutations. Through NLP capabilities, ChatGPT can help researchers quickly parse through complex genomic literature and update genome annotations with the latest findings (Chen et al., 2023). By analyzing genomic sequences, ChatGPT can provide insights into the potential impact of mutations. This is especially valuable for understanding the genetic underpinnings of complex diseases such as cancer, neurodegenerative disorders, and rare genetic diseases. Recent studies have demonstrated that ChatGPT can assist in predicting the pathogenicity of genetic variants, allowing researchers to prioritize variants for experimental validation (Patrinos et al., 2023).

2.2 Drug Discovery and Development

AI-powered models, including ChatGPT, are transforming the landscape of drug discovery. In traditional drug discovery, the identification of new therapeutic targets, lead compounds, and drug candidates is a lengthy and expensive process. ChatGPT helps reduce time and costs by automating literature searches, proposing novel drug compounds, and predicting drug-target interactions.

ChatGPT can assist researchers in sifting through high-throughput screening results to identify potential drug candidates. By analyzing large chemical libraries, ChatGPT can predict which molecules are likely to interact with specific biological targets, improving the efficiency of virtual screening (Chakraborty et al., 2023). ChatGPT can also generate hypotheses about the chemical structure and properties of novel compounds. By analyzing existing databases like PubChem, ChatGPT can suggest potential modifications to chemical structures, helping medicinal chemists design more potent and specific drugs (Caspi & Karp, 2024). Personalized medicine, which tailors drug treatments to individuals based on their genetic makeup, is an emerging area of healthcare. ChatGPT can help predict how patients with different genetic profiles will respond to particular drugs, thereby improving the effectiveness of treatments and minimizing adverse drug reactions (Fatima et al., 2024).

Clinical Diagnostics and Decision Support

The application of ChatGPT in clinical diagnostics has great promise. In clinical settings, accurate and timely diagnosis is critical for improving patient outcomes. ChatGPT can assist clinicians by analyzing patient data, suggesting possible diagnoses, and recommending personalized treatment plans based on the latest clinical guidelines and research. ChatGPT can integrate with electronic health record (EHR) systems to help clinicians make more informed decisions. By analyzing patient histories, lab results, and diagnostic tests, ChatGPT can offer diagnostic suggestions, potential causes for observed symptoms, and recommend further tests or treatments (Deiana et al., 2023). Another critical area is the analysis of medical imaging data. ChatGPT, integrated with image analysis tools, can assist radiologists in interpreting X-rays, MRIs, and CT scans. By combining image data with patient medical records, ChatGPT can enhance diagnostic accuracy, reduce errors, and speed up the process of diagnosis (Bhargava et al., 2023).

3. ChatGPT in Medical Education

Medical education is an evolving field, and the integration of AI can significantly enhance the learning process for students and professionals. ChatGPT's ability to provide real-time explanations, generate case studies, and interact with students offers an innovative approach to medical teaching.

3.1 Interactive Learning

ChatGPT's interactive capabilities provide students with a conversational platform for asking questions and clarifying complex concepts in real time. Medical students can use ChatGPT as a supplementary learning tool to reinforce their understanding of anatomy, physiology, pharmacology, and other medical disciplines.

ChatGPT can generate medical case studies that simulate real-world clinical scenarios. By presenting students with case-based problems, ChatGPT helps them develop critical thinking, problem-solving, and diagnostic skills. Students can interact with the AI to gather additional details and explore potential treatment options (Gilson et al., 2023).

ChatGPT can serve as a personalized tutor, adjusting its responses to suit the student's level of knowledge. It can identify knowledge gaps and provide targeted explanations or practice problems to help student's master complex medical topics (Kıyak & Kononowicz, 2024).

3.2 Knowledge Dissemination

In addition to aiding individual learning, ChatGPT can help disseminate medical knowledge on a global scale. By generating summaries of recent research, ChatGPT makes cutting-edge scientific advancements more accessible to healthcare professionals worldwide, helping them stay up-to-date with the latest clinical guidelines, treatment protocols, and emerging technologies (Jeyaraman et al., 2023).

4. Ethical Considerations and Challenges

As with all AI applications, the use of ChatGPT in bioinformatics raises several ethical challenges that need to be addressed to ensure responsible and beneficial use of the technology.

4.1 Data Privacy and Security

Data privacy remains one of the most pressing concerns when integrating AI models into healthcare and bioinformatics. ChatGPT, when used in clinical and research settings, has access to sensitive data, including patient health records, genomic information, and research datasets. Strict regulatory frameworks must be established to ensure that this data is handled securely and that individuals' privacy rights are respected (Minssen et al., 2023).
In healthcare settings, AI models like ChatGPT must comply with the Health Insurance Portability and Accountability Act (HIPAA) to protect patient privacy. Failure to adhere to these regulations could result in breaches of confidentiality and loss of trust in AI-driven technologies.

AI Bias and Fairness

AI models, including ChatGPT, are trained on large datasets, which may contain inherent biases. If not properly managed, these biases can be reflected in the model's outputs, potentially leading to unfair or discriminatory recommendations. One particular area where bias is of concern is in medical diagnostics. ChatGPT's predictions and recommendations must be rigorously tested to ensure that they do not perpetuate biases related to gender, race, or socioeconomic status (De Angelis et al., 2023; Darkhabani et al., 2023).

4.3 Misinformation and Trustworthiness

ChatGPT's ability to generate coherent and contextually relevant text raises concerns about the potential for spreading misinformation, particularly in the context of health-related content. It is crucial to ensure that the content generated by ChatGPT is scientifically accurate and based on reputable sources (Sharun et al., 2023).
The integration of ChatGPT into bioinformatics represents a transformative shift in research, education, and clinical applications. As artificial intelligence continues to evolve, its role in biological sciences is becoming more prominent, streamlining complex analyses, accelerating discoveries, and enhancing personalized medicine. The rapid adoption of ChatGPT and similar AI-driven models in bioinformatics is redefining the landscape of genomics, proteomics, and systems biology, contributing to more efficient and accurate data processing and interpretation (Xu, 2023; Zhou et al., 2024).

- **Revolutionizing Research**

ChatGPT has demonstrated significant potential in expediting various aspects of bioinformatics research, including literature review automation (Chen et al., 2023), protein structure prediction (Wang et al., 2024), and genetic data interpretation (Emmert-Streib, 2024). AI-driven models are enhancing drug discovery by predicting molecular interactions (Chakraborty et al., 2023), thereby reducing experimental costs and time. Additionally, ChatGPT assists in scientific writing, improving the efficiency of manuscript preparation, grant applications, and coding in bioinformatics workflows (Sänger et al., 2024). However, concerns regarding data accuracy, model biases, and ethical considerations remain crucial challenges that need continuous assessment and improvement (Minssen et al., 2023; Misra & Chandwar, 2023).

- **Advancing Education**

ChatGPT has significantly influenced bioinformatics education by providing personalized learning experiences, automating assessment tasks, and serving as a virtual tutor (Kang et al., 2024). Large language models have enhanced curriculum design by generating case-based multiple-choice questions (Kıyak & Kononowicz, 2024) and supporting computational biology training (Shue et al., 2023). Furthermore, AI has bridged the gap between theoretical knowledge and practical applications by assisting students in writing code, debugging scripts, and understanding complex biological datasets (Rahman & Wong, 2024; Piccolo et al., 2023). However, over-reliance on AI-generated information may impact critical thinking skills, emphasizing the need for human oversight in educational applications (Doyal et al., 2023).

- **Clinical Applications**

ChatGPT's integration into clinical bioinformatics has facilitated advancements in precision medicine, patient stratification, and disease modeling (Baumgartner, 2023). AI-driven algorithms enhance the accuracy of genomic data interpretation, contributing to improved diagnostics and treatment strategies (Fatima et al., 2024). In nephrology, ChatGPT has proven valuable in navigating personalized medicine literature (Aiumtrakul et al., 2023), while in oncology, it assists in identifying potential drug targets (Pal et al., 2023). Additionally, the chatbot's ability to analyze electronic health records (Chen et al., 2024) and triage patients (Kaboudi et al., 2024) highlights its clinical relevance. Nevertheless, issues related to data privacy, regulatory compliance, and ethical implications warrant rigorous scrutiny (Wen & Wang, 2023; Hu et al., 2024).
Despite its numerous advantages, the application of ChatGPT in bioinformatics is not without limitations. AI-generated outputs may contain errors, leading to misinformation if not properly validated (Misra & Chandwar, 2023). Additionally, ethical concerns regarding data security, intellectual property, and authorship attribution need to be addressed (Doyal et al., 2023; Sharun et al., 2023). Enhancing the explainability of AI models and incorporating human-in-the-loop approaches are crucial to mitigating these risks (Xu, 2023). Future developments should focus on integrating multimodal AI systems that combine textual, visual, and numerical data to improve interpretability and decision-making (Zhou et al., 2024; Wang et al., 2024). ChatGPT is revolutionizing bioinformatics by accelerating research, personalizing education, and improving clinical applications. While its capabilities continue to expand, ensuring responsible AI deployment through continuous validation, ethical considerations, and regulatory compliance remains paramount. The synergy between artificial intelligence and bioinformatics holds immense promise for shaping the future of biological and medical sciences, paving the way for groundbreaking discoveries and improved healthcare outcomes (Vieira et al., 2024; Perkel, 2023).
The evolution of artificial intelligence, particularly large language models like ChatGPT, has sparked discussions about their transformative impact on various domains, including biomedical research, healthcare, and education. Several studies have highlighted ChatGPT's utility in simplifying complex medical content, enhancing communication, and facilitating data extraction from biomedical records (Al-Moghrabi et al., 2024; Cinquin, 2024; Huang et al., 2024). Its ability to generate scientific abstracts and differentiate between human-written and AI-generated texts has further solidified its role in research and publication (Gao et al., 2023; Liao et al., 2023). Additionally, the integration of ChatGPT in clinical and translational medicine has

demonstrated promising applications for patient care and decision-making (Xue et al., 2023; Wong et al., 2023). However, concerns about bias, reliability, and ethical considerations remain significant challenges that must be addressed (Tian et al., 2023; Patel et al., 2024).

In the field of bioinformatics, ChatGPT and other AI-driven tools are being leveraged for metadata integrity, computational biology, and biomedical literature search, providing researchers with enhanced methodologies for data analysis and interpretation (Caliskan et al., 2023; Jin et al., 2024; Sarumi & Heider, 2024). The emergence of AI-powered tools like BioCoder underscores the growing reliance on machine learning for bioinformatics code generation and problem-solving (Tang et al., 2024). Furthermore, the intersection of ChatGPT with synthetic biology research offers insights into emerging trends and potential advancements in genetic engineering (Tong & Zhang, 2023). Despite these advantages, the need for rigorous validation and refinement of AI-generated results remains critical to ensuring scientific integrity (Pal et al., 2024; Lubiana et al., 2023).

Medical and dental research have also benefited from ChatGPT's ability to streamline literature review processes, improve diagnostic accuracy, and provide educational support (Fatani, 2023; Huang et al., 2023). ChatGPT has been explored as a virtual consultant for educating families about medical conditions such as retinopathy of prematurity, demonstrating its potential to enhance patient communication (Durmaz Engin et al., 2024). The role of AI in clinical note generation and medical documentation has further optimized healthcare workflows (Nguyen & Pepping, 2023). Nonetheless, the challenge of ensuring factual accuracy, particularly in fields requiring high precision such as radiology and surgery, necessitates continuous improvements in AI models (Amin et al., 2023; Schopow et al., 2023; Wu & Zhang, 2024).

From an educational perspective, ChatGPT has reshaped medical training by assisting students with exam preparation, research, and clinical case analysis (Haze et al., 2023; Arif et al., 2023). The tool's ability to provide explanations, generate practice questions, and support interactive learning has made it a valuable asset in medical education (Ashraf & Ashfaq, 2024; Dergaa et al., 2024). However, while ChatGPT has demonstrated competence in answering medical licensing exam questions, its limitations in comprehending nuanced clinical scenarios suggest that human oversight remains indispensable (Huang et al., 2024; Tian et al., 2023). AI's role in academic publishing has also sparked discussions on plagiarism and ethical authorship practices, necessitating the development of refined algorithms to ensure originality in scientific writing (Pal et al., 2024).

Looking forward, the integration of ChatGPT and similar AI-driven systems into biomedical and healthcare domains presents both opportunities and challenges. While AI has the potential to revolutionize diagnostics, patient management, and research methodologies, the ethical implications of reliance on machine-generated content require continuous scrutiny (Ruksakulpiwat et al., 2023; Zhao & Wu, 2023). The future of AI in medicine will depend on collaborative efforts to improve model accuracy, mitigate biases, and establish clear guidelines for responsible AI use (Li et al., 2024; Tan et al., 2024). As AI continues to evolve, interdisciplinary research and regulatory frameworks will be essential in ensuring its ethical and effective application in healthcare and scientific discovery (Patel et al., 2024; Inojosa et al., 2023).

5. Conclusion and Future Directions

In conclusion, ChatGPT has immense potential to revolutionize bioinformatics by accelerating data analysis, improving clinical decision-making, and enhancing educational practices. However, to fully harness its capabilities, ethical concerns surrounding data privacy, AI bias, and misinformation must be carefully addressed. Continued research and regulatory oversight are essential to ensure that ChatGPT and similar AI models are used responsibly and effectively in bioinformatics. As we look to the future, ChatGPT and other AI models will play an increasingly important role in shaping the landscape of biomedical research and healthcare. With continued advancements in AI technology, ChatGPT will likely become an indispensable tool in the next generation of bioinformaticians, medical professionals, and educators.

The rapid evolution of artificial intelligence, particularly large language models, is revolutionizing the fields of biomedical research, healthcare, and education. These technologies offer remarkable potential to enhance data analysis, streamline workflows, and improve accessibility to information. From simplifying complex medical content to generating scientific insights, AI is proving to be a valuable asset in advancing knowledge and efficiency. However, the widespread adoption of AI requires careful consideration of ethical implications, ensuring that its applications remain transparent, unbiased, and reliable.

In the realm of bioinformatics, AI-driven tools are transforming how researchers process and interpret vast datasets, opening new avenues for discovery and innovation. With capabilities such as predictive modeling and automated analysis, AI is accelerating progress in areas like computational biology and genetic research. Despite its advantages, maintaining scientific integrity through rigorous validation and oversight remains a critical challenge. Medical and dental research have also benefited from AI's ability to enhance diagnostic accuracy and patient communication. AI-powered systems are increasingly being integrated into clinical decision-making, offering support in complex cases and providing valuable educational resources. However, reliance on AI must be balanced with human expertise to mitigate risks associated with misinformation and errors, particularly in high-stakes medical fields.

Education and training in healthcare are being reshaped by AI's ability to facilitate learning through personalized content, interactive simulations, and adaptive assessments. While AI serves as an effective educational tool, it is essential to recognize its limitations and ensure that it complements, rather than replaces, traditional teaching methodologies. Human oversight and critical thinking remain indispensable in cultivating well-rounded professionals. Looking ahead, the integration of AI into biomedical and healthcare domains presents both opportunities and challenges. The key to unlocking its full potential lies in interdisciplinary collaboration, ethical guidelines, and continuous refinement of AI technologies. As these systems continue to evolve, responsible development and implementation will be crucial in shaping a future where AI enhances human capabilities without compromising ethical and professional standards.

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