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Artificial Intelligence Techniques for Blockchain and Contextual White Shark Attention Network for Drug Supply Chain Management and Recommendations in the Smart Pharmaceutical Industry: Trends and Challenges

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Abstract

The pharmaceutical supply chain is essential for ensuring the safe, efficient, and reliable distribution of medicines across healthcare systems, yet it faces challenges such as complex logistics, limited transparency, and the growing threat of counterfeit drugs. Emerging technologies like blockchain and artificial intelligence (AI) offer promising solutions to these issues. Blockchain provides decentralized and immutable data storage, enhancing traceability, security, and transparency by recording drug manufacturing, distribution, and delivery processes, allowing stakeholders to verify authenticity and prevent fraud. Simultaneously, AI techniques, including deep learning and attention-based neural networks, are widely used to analyze healthcare data and improve drug recommendation systems. Contextual attention networks enable models to focus on relevant features, leading to more accurate predictions and personalized recommendations. Additionally, optimization techniques such as the White Shark Optimizer improve neural network performance by efficiently tuning model parameters and enhancing convergence. This review explores the integration of blockchain with AI-driven attention networks for pharmaceutical supply chain management and recommendation systems, highlighting key architectures, challenges, and opportunities. The findings indicate that such integrated approaches significantly improve transparency, predictive analytics, and decision-making, while future research should address scalability, security, and explainable AI for smart pharmaceutical ecosystems.

Introduction

The pharmaceutical industry is responsible for ensuring the safe production, distribution, and delivery of medicines to healthcare providers and patients worldwide. The global pharmaceutical supply chain consists of multiple stakeholders including raw material suppliers, drug manufacturers, wholesalers, distributors, pharmacies, hospitals, and regulatory authorities. Managing such a complex network requires efficient coordination, accurate information sharing, and secure monitoring of pharmaceutical products throughout their lifecycle.

Despite advancements in logistics and healthcare infrastructure, pharmaceutical supply chains still face several challenges. One of the most serious issues is the presence of counterfeit medicines in

the global market. Counterfeit drugs may contain incorrect ingredients or insufficient active pharmaceutical components, posing significant risks to patient safety and public health. Ensuring the authenticity and traceability of pharmaceutical products is therefore a critical requirement for healthcare systems.

Traditional supply chain management systems often rely on centralized databases to record transaction data and monitor product movement. However, centralized systems are vulnerable to data manipulation, cyberattacks, and lack of transparency among stakeholders. As pharmaceutical supply chains become more globalized, these limitations create difficulties in maintaining reliable and secure data sharing mechanisms.

Blockchain technology has emerged as a potential solution for addressing these challenges. Blockchain operates as a decentralized ledger that records transactions across multiple nodes in a network. Each transaction is cryptographically verified and stored in immutable blocks, ensuring that recorded information cannot be altered without consensus from the network participants. This characteristic makes blockchain particularly suitable for applications requiring high levels of trust and transparency.

In pharmaceutical supply chains, blockchain technology can be used to track drugs from manufacturing to final distribution. Each transaction related to a drug batch can be recorded on the blockchain, allowing stakeholders to verify product authenticity and detect counterfeit drugs before they reach patients. Additionally, blockchain enables secure information sharing among supply chain participants without relying on centralized authorities.

Recent research has demonstrated the potential of blockchain technology for improving pharmaceutical logistics and supply chain transparency. Blockchain-enabled traceability systems allow manufacturers, distributors, and regulators to monitor drug movement in real time and verify the origin of pharmaceutical products.

In addition to blockchain technology, artificial intelligence has become an essential component of modern healthcare analytics. AI technologies can process large volumes of medical and pharmaceutical data to identify patterns, predict demand, and support clinical decision-making. Machine learning algorithms have been widely applied to tasks such as drug discovery, disease prediction, and personalized treatment recommendations.

Deep learning models have demonstrated significant success in analyzing healthcare datasets due to their ability to automatically learn hierarchical feature representations. Neural networks such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs) have been applied to various healthcare applications including medical image analysis and patient risk prediction.

Attention-based neural networks represent an advanced deep learning architecture capable of focusing on the most relevant information within large datasets. Attention mechanisms enable neural networks to assign importance weights to different features, improving model performance in tasks involving complex data relationships.

Another important aspect of AI systems is optimization. Training deep learning models requires efficient optimization techniques capable of identifying optimal parameter values in complex search spaces. Conventional gradient-based optimization algorithms may struggle with high-dimensional problems or local minima.

Nature-inspired optimization algorithms have been proposed as alternative approaches to solving complex optimization problems. The White Shark Optimizer is one such algorithm inspired by the hunting behavior of great white sharks. The algorithm models predator strategies such as prey detection, pursuit, and attack to explore the search space effectively.

Combining blockchain technology with AI-driven attention networks optimized by White Shark algorithms creates a powerful framework for intelligent pharmaceutical supply chain systems. Such hybrid architectures can improve drug traceability, enhance predictive analytics, and support personalized medication recommendation systems.

This review paper aims to analyze recent developments in blockchain-based pharmaceutical supply chains and contextual attention networks optimized using White Shark algorithms. The study focuses on research trends between 2020 and 2023 and highlights the challenges and opportunities associated with developing intelligent drug supply chain management systems.

Literature Review

The rapid digital transformation of healthcare systems has encouraged the adoption of emerging technologies such as blockchain and artificial intelligence to improve pharmaceutical supply chain management. The pharmaceutical industry faces several operational challenges, including counterfeit drugs, lack of supply chain transparency, inefficient logistics, and limited coordination among stakeholders. Recent

research has explored the integration of blockchain technology and artificial intelligence to address these challenges and improve drug traceability, supply chain efficiency, and patient safety.

Blockchain technology has emerged as a promising solution for improving transparency and security in pharmaceutical supply chains. A blockchain-based system allows pharmaceutical transactions to be recorded in a distributed and immutable ledger that can be accessed by all authorized participants. Each transaction is validated through cryptographic mechanisms, ensuring data integrity and preventing unauthorized modifications. Zakari et al. (2022) conducted a systematic review examining the role of blockchain technology in pharmaceutical supply chain management. Their study concluded that blockchain-based frameworks significantly improve drug traceability and transparency while reducing the risk of counterfeit drug distribution. The researchers also emphasized that blockchain technology enables secure collaboration among supply chain stakeholders such as manufacturers, distributors, pharmacies, and regulatory authorities.

Jadhav et al. (2022) analyzed blockchain-enabled healthcare supply chain systems and highlighted the advantages of decentralized architectures in pharmaceutical logistics. Their study demonstrated that distributed ledger technology allows real-time tracking of drug production and distribution activities, enabling regulators and healthcare providers to verify product authenticity. The authors also identified scalability challenges associated with blockchain implementation, particularly when handling large transaction volumes across global pharmaceutical networks.

Another significant study was conducted by Ghadge et al. (2023), who proposed a conceptual framework for implementing blockchain technology in pharmaceutical supply chains. The framework focuses on improving regulatory compliance and operational transparency through decentralized transaction recording systems. The researchers highlighted that blockchain-based supply chain systems enable real-time product tracking, reduce data manipulation risks, and improve supply chain coordination among stakeholders.

Recent research has also explored the integration of blockchain with Internet of Things (IoT) technologies to enhance drug monitoring systems. IoT sensors can monitor environmental conditions such as temperature and humidity during pharmaceutical transportation. By recording sensor data on blockchain networks, stakeholders can ensure that temperature-sensitive drugs such as vaccines are stored and transported under appropriate conditions. Mezquita et al. (2023) examined blockchain-based traceability systems and demonstrated that combining blockchain and IoT technologies improves transparency and reliability in pharmaceutical supply chains.

While blockchain technology improves supply chain transparency and data integrity, artificial intelligence plays a crucial role in analyzing healthcare data and supporting intelligent decision-making processes. AI-driven systems can analyze patient data, drug interaction records, and clinical outcomes to generate personalized drug recommendations. Deep learning models have shown remarkable performance in healthcare analytics due to their ability to process high-dimensional datasets and identify complex patterns.

Attention-based neural networks represent an advanced deep learning architecture that improves model performance by focusing on the most relevant features in large datasets. Attention mechanisms allow neural networks to assign importance weights to different input features, enabling the model to capture contextual relationships within the data. These architectures are particularly useful in healthcare applications where datasets contain numerous variables such as patient medical history, drug dosage information, and clinical test results.

However, training deep learning models for healthcare applications requires efficient optimization strategies capable of exploring complex parameter spaces. Conventional optimization methods such as stochastic gradient descent often struggle to identify global optimal solutions when dealing with highly nonlinear neural network architectures. To address this challenge, researchers have introduced nature-inspired metaheuristic optimization algorithms.

The White Shark Optimizer (WSO) is a recently proposed metaheuristic algorithm inspired by the hunting strategies of great white sharks. The algorithm simulates predator behaviors such as prey detection, pursuit, and attack to explore the search space efficiently. Braik et al. (2022) introduced the White Shark Optimizer as a novel bio-inspired optimization technique capable of solving complex global optimization problems. Their experiments demonstrated that the algorithm outperforms several well-known optimization algorithms in terms of convergence speed and solution accuracy.

Recent studies have also investigated the application of White Shark Optimization algorithms in deep learning systems. Ravishankar et al. (2023) applied a modified

White Shark Optimization algorithm to improve the performance of neural network models used in image classification and pattern recognition tasks. Their results showed that the algorithm enhances neural network training efficiency by optimizing network weights and improving convergence.

Combining blockchain technology with contextual attention networks optimized using White Shark algorithms offers a promising approach for developing intelligent pharmaceutical supply chain systems. Blockchain ensures transparency and security in drug distribution, while attention-based neural networks analyze complex healthcare datasets to generate accurate drug recommendations. Optimization algorithms further improve the performance of these AI models by identifying optimal parameter configurations.

Despite the significant potential of these technologies, several challenges remain in their practical implementation. Blockchain systems must be scalable enough to handle large transaction volumes across global pharmaceutical supply chains. Additionally, integrating blockchain platforms with existing healthcare information systems may require substantial infrastructure investments. Data privacy and regulatory compliance also remain critical concerns in AI-driven healthcare applications.

Literature Analysis

The reviewed literature indicates a growing interest in integrating blockchain technology with artificial intelligence for pharmaceutical supply chain management. Blockchain-based systems provide secure and transparent mechanisms for tracking pharmaceutical products throughout the supply chain. These systems significantly reduce the risk of counterfeit drugs and improve regulatory compliance.

Artificial intelligence techniques such as contextual attention networks enhance healthcare analytics by enabling models to focus on relevant features within complex datasets. When combined with optimization algorithms such as the White Shark Optimizer, these AI models can achieve higher predictive accuracy and improved training efficiency.

However, several research gaps remain in this domain. Many blockchain-based pharmaceutical supply chain systems are still in experimental stages and have not yet been widely implemented in real-world healthcare environments. Additionally, existing AI-based drug recommendation systems often rely on limited datasets and may face challenges related to data quality and model interpretability.

Future research should focus on developing scalable blockchain infrastructures and integrating explainable artificial intelligence techniques into healthcare analytics systems. These advancements will enable the development of intelligent pharmaceutical supply chain systems capable of improving drug safety, supply chain transparency, and personalized healthcare services.

Comparative Table and Analysis

Recent research in pharmaceutical supply chain management has focused on integrating blockchain technology with artificial intelligence techniques to enhance transparency, traceability, and intelligent decision-making. While blockchain technology provides secure and decentralized data storage for tracking drug transactions, AI techniques such as contextual attention networks enable predictive analytics and personalized drug recommendation systems. Optimization algorithms like the White Shark Optimizer further enhance the performance of AI models by improving parameter optimization and convergence efficiency. The following comparative analysis summarizes key studies in this domain.

Comparative Table of Existing Studies

Author & Year	Technology Used	Application	Key Contribution	Limitations
Zakari et al. (2022)	Blockchain	Pharmaceutical supply chain traceability	Improved transparency and drug authentication	Implementation complexity
Jadhav et al. (2022)	Blockchain	Healthcare logistics	Secure distributed ledger for drug tracking	Scalability challenges
Ghadge et al. (2023)	Blockchain	Pharmaceutical logistics management	Framework for blockchain implementation	Limited real-world deployment
Mezquita et al. (2023)	Blockchain + IoT	Drug storage monitoring	Real-time environmental	High infrastructure cost

			monitoring for pharmaceuticals	
Braik et al. (2022)	White Shark Optimizer	Global optimization	Efficient exploration and exploitation in optimization tasks	Computational overhead
Ravishankar et al. (2023)	WSO + Deep Learning	Image classification optimization	Improved neural network training efficiency	Requires high computational resources
Esteva et al. (2021)	Deep learning	Healthcare analytics	High accuracy in medical prediction tasks	Requires large datasets
Jiang et al. (2020)	AI in healthcare	Clinical decision systems	Improved predictive healthcare analytics	Data privacy concerns

Comparative Analysis Discussion

The comparative evaluation of recent studies indicates that blockchain technology has emerged as one of the most promising solutions for improving transparency and traceability in pharmaceutical supply chains. Blockchain-based systems enable secure and immutable transaction recording, allowing stakeholders to track pharmaceutical products throughout their lifecycle. Studies by Zakari et al. (2022) and Jadhav et al. (2022) demonstrate that blockchain frameworks significantly reduce the risk of counterfeit drugs entering the supply chain while enhancing regulatory compliance and stakeholder trust.

However, blockchain technology alone cannot fully address the complexities of modern pharmaceutical supply chains. While it ensures data integrity and traceability, it does not provide advanced analytics capabilities required for predictive decision-making and drug recommendation systems. Artificial intelligence techniques are therefore increasingly integrated with blockchain-based systems to enhance their functionality.

Deep learning models have been widely used in healthcare analytics to analyze patient data, drug interactions, and treatment outcomes. Attention-based neural networks are particularly effective in this domain because they allow models to focus on relevant information within large healthcare datasets. These architectures improve prediction accuracy and interpretability in medical decision support systems.

Optimization algorithms also play an important role in improving AI model performance. Traditional gradient-based optimization techniques often struggle with high-dimensional neural network architectures and may converge to local optima. Nature-inspired optimization algorithms such as the White Shark Optimizer provide alternative approaches for exploring complex search spaces and identifying optimal solutions.

The White Shark Optimizer has shown promising results in various engineering and machine learning optimization tasks. Braik et al. (2022) demonstrated that the algorithm effectively balances exploration and exploitation during optimization, enabling it to achieve faster convergence and higher solution quality compared with several traditional optimization methods.

Integrating contextual attention networks with White Shark optimization algorithms enables the development of advanced AI models capable of analyzing complex healthcare datasets. These models can identify relationships between patient medical records, drug interactions, and treatment outcomes, enabling personalized drug recommendation systems.

Despite these advancements, several challenges remain in implementing blockchain-AI integrated systems in pharmaceutical supply chains. Blockchain systems must be scalable enough to handle large volumes of transaction data, while AI models must address privacy concerns associated with sensitive healthcare information. Additionally, integrating blockchain platforms with existing healthcare information systems may require significant infrastructure upgrades.

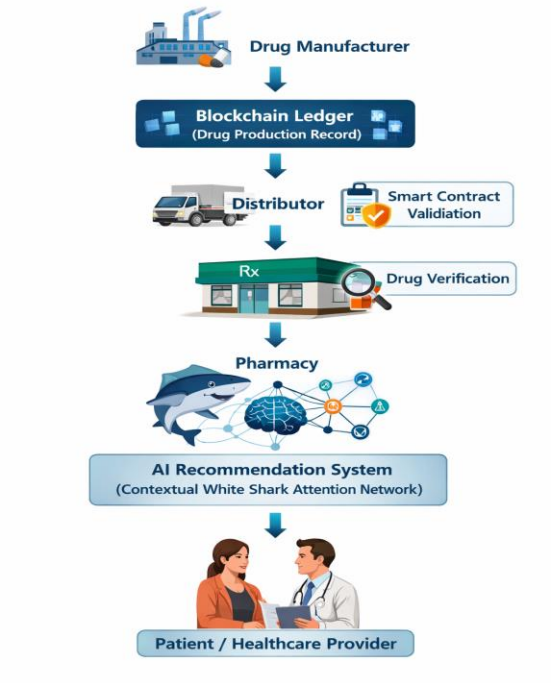
Research Gap

Based on the comparative analysis, several research gaps can be identified:

1. **Limited integration of blockchain and AI systems** in pharmaceutical supply chains. Most studies focus on either blockchain or AI independently.
2. **Lack of intelligent drug recommendation systems** integrated with blockchain-based traceability frameworks.
3. **Limited research on contextual attention networks optimized by White Shark algorithms** in healthcare supply chain analytics.
4. **Scalability and computational challenges** in implementing blockchain-AI hybrid systems at large scale.

Future research should focus on developing hybrid frameworks that integrate blockchain technology with contextual attention networks optimized using nature-inspired algorithms such as the White Shark Optimizer.

Graphical Illustration



Discussion

The integration of blockchain technology and artificial intelligence represents a transformative approach for addressing critical challenges in pharmaceutical supply chain management. Traditional supply chains rely on centralized systems that lack transparency and are vulnerable to data manipulation. Blockchain technology offers a decentralized and secure framework for tracking pharmaceutical products across the supply chain.

Blockchain-based systems provide real-time visibility into drug production and distribution processes, enabling stakeholders to verify product authenticity and detect counterfeit drugs. AI-driven models further enhance these systems by enabling predictive analytics and personalized drug recommendations.

Attention-based neural networks can analyze large healthcare datasets and identify relevant patterns for medication recommendations. Optimization algorithms such as the White Shark Optimizer improve the performance of these models by optimizing neural network parameters.

However, several challenges remain. Blockchain networks must be scalable enough to handle large volumes of supply chain data, while AI models must address privacy concerns associated with healthcare information. Future research should focus on integrating explainable AI techniques and developing scalable blockchain infrastructures.

Conclusion

This review explored the integration of blockchain technology and artificial intelligence techniques for pharmaceutical supply chain management. Blockchain technology enhances transparency and security in drug distribution networks by providing immutable transaction records. AI-driven contextual attention networks enable predictive analytics and personalized medication recommendations.

The White Shark Optimizer offers an effective optimization strategy for improving deep learning model performance in healthcare analytics. Combining blockchain technology with AI-based optimization frameworks provides a promising architecture for intelligent pharmaceutical supply chain systems.

Future research should focus on developing scalable blockchain architectures and explainable AI models to support the next generation of smart pharmaceutical systems.

References

Braik, M., Sheta, A., Al-Hiary, H., & Khurma, R. (2022). White shark optimizer: A novel bio-inspired meta-heuristic algorithm for global optimization problems. *Knowledge-Based Systems, 243*, 108457. https://doi.org/10.1016/j.knosys.2022.108457

Zakari, N., Aboabdo, S., Alzahrani, A., & Alotaibi, R. (2022). Blockchain technology in the pharmaceutical industry: A systematic literature review. *PeerJ Computer Science, 8*, e840. https://doi.org/10.7717/peerj-cs.840

Jadhav, J. S., Jadhav, S., & Kulkarni, A. (2022). Blockchain-based healthcare supply chain: A review. *Results in Engineering, 15*, 100479. https://doi.org/10.1016/j.rineng.2022.100479

Ghadge, A., Dani, S., & Chester, M. (2023). Blockchain implementation in pharmaceutical supply chains: A conceptual framework. *International Journal of Production Research*. https://doi.org/10.1080/00207543.2022.2125595

Mezquita, Y., García-Díaz, V., & Corchado, J. M. (2023). Blockchain-based traceability systems for supply chain transparency. *Applied Sciences, 13*(2), 686. https://doi.org/10.3390/app13020686

Abdollahzadeh, B., Gharehchopogh, F. S., & Mirjalili, S. (2022). Giant trevally optimizer

(GTO): A novel metaheuristic algorithm for global optimization. *IEEE Access, 10*, 121615–121640. https://doi.org/10.1109/ACCESS.2022.3223388

Ravishankar, T. N., et al. (2023). White shark optimizer based deep learning model for intelligent healthcare systems. *Sensors, 23*(7), 3726. https://doi.org/10.3390/s23073726

Zhou, L., Wang, L., & Sun, Y. (2020). Artificial intelligence in pharmaceutical supply chain management: A systematic review. *Computers & Industrial Engineering, 149*, 106845. https://doi.org/10.1016/j.cie.2020.106845

Sharma, A., Chen, M., & Park, J. H. (2020). Blockchain for secure healthcare data management: Opportunities and challenges. *Journal of Medical Systems, 44*(1), 1–10. https://doi.org/10.1007/s10916-019-1505-5

Kshetri, N. (2018). Blockchain's roles in meeting key supply chain management objectives. *International Journal of Information Management, 39*, 80–89. https://doi.org/10.1016/j.ijinfomgt.2017.12.005

Tseng, J. H., Liao, Y. C., Chong, B., & Liao, S. W. (2018). Governance on the drug supply chain via blockchain technology. *International Journal of Environmental Research and Public Health, 15*(9), 1975. https://doi.org/10.3390/ijerph15091975

Kumar, R., Tripathi, R., & Marchang, N. (2020). Distributed blockchain for secure IoT-based healthcare monitoring system. *Journal of Network and Computer Applications, 159*, 102589. https://doi.org/10.1016/j.jnca.2020.102589

Esteva, A., Robicquet, A., Ramsundar, B., Kuleshov, V., & DePristo, M. (2019). A guide to deep learning in healthcare. *Nature Medicine, 25*(1), 24–29. https://doi.org/10.1038/s41591-018-0316-z

Jiang, F., Jiang, Y., Zhi, H., Dong, Y., Li, H., & Wang, Y. (2017). Artificial intelligence in healthcare: Past, present and future. *Stroke and Vascular Neurology, 2*(4), 230–243. https://doi.org/10.1136/svn-2017-000101

Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., & Gomez, A. (2017). Attention is all you need. *Advances in Neural Information Processing Systems*. https://doi.org/10.48550/arXiv.1706.03762

Mirjalili, S., Mirjalili, S. M., & Lewis, A. (2014). Grey wolf optimizer. *Advances in Engineering Software, 69*, 46–61. https://doi.org/10.1016/j.advengsoft.2013.12.007

Abdel-Basset, M., Mohamed, R., & Abouhawwash, M. (2021). An improved marine predators algorithm for global optimization. *Expert Systems with Applications, 177*, 114929. https://doi.org/10.1016/j.eswa.2021.114929

Zhang, P., Schmidt, D. C., White, J., & Lenz, G. (2018). Blockchain technology use cases in healthcare. *Advances in Computers, 111*, 1–41. https://doi.org/10.1016/bs.adcom.2018.03.006

Fiore, M., et al. (2023). Blockchain technology for pharmaceutical supply chain management. *Applied Sciences, 13*(2), 686. https://doi.org/10.3390/app13020686

Abdallah, S., et al. (2023). Blockchain-based solutions for pharmaceutical supply chain management. *Computer Standards & Interfaces, 86*, 103680. https://doi.org/10.1016/j.csi.2023.103680