

Artificial Intelligence in E-commerce: Applications, Challenges and Future Trends

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Abstract:

The rapid development of digital technologies has made e-commerce one of the most dynamic sectors in the global economy. With the explosive growth of online shopping, massive amounts of transaction data, and increasingly diverse consumer demands, traditional e-commerce models face significant challenges in terms of efficiency, personalization, and security. Against this backdrop, Artificial Intelligence (AI) has become a core driver of innovation, providing new approaches to enhance user experience, optimize resource allocation, and mitigate risk. This article discusses the application status, impact and future development trend of artificial intelligence technology in the field of e-commerce. The research systematically analyzes the specific practices of AI in personalized recommendation, supply chain optimization and fraud detection, and shows that AI technology significantly improves the operational efficiency, user experience and transaction security of e-commerce platforms. At the same time, this article also points out the problems of data security risk and algorithm bias in AI application, and puts forward corresponding countermeasures. In the future, with the integration of large models, edge computation and other technologies, AI will further promote the development of e-commerce towards full-link intellectualization and virtual-real integration experience, reshape the industry ecology and value logic, and achieve sustainable innovation and high-quality development.

Keywords: Artificial intelligence; e-commerce; machine learning.

1. Introduction

In the tide of the digital economy, e-commerce platforms, as the core hub connecting supply and demand, have profoundly reshaped the business ecosystem and consumption patterns. Electronic Commerce (E-commerce), in short, is a form of commercial activity that realizes the transaction of goods and services, capital circulation, and information exchange through electronic means such as the Internet. From simple online yellow page displays in the early days to today's ecological system integrating transactions, social interactions, and experiences, its connotation and boundaries have been continuously expanding.

Looking back at the development history of e-commerce, technological iteration is the core driving force. As an important venue for transactions between merchants and customers, e-commerce platforms have greatly expanded market boundaries, improved the circulation efficiency of goods and services, and constituted a significant part of driving China's economic development [1]. In the 1970s, the emergence of Electronic Data Interchange (EDI) technology made it possible to exchange electronic documents for cross-border trade between enterprises, which can be regarded as the embryonic form of e-commerce. In the 1990s, with the popularization of the Internet, platforms such as Amazon (launched in 1995) and Alibaba (founded in 1999) emerged, pushing e-commerce from enterprise-level transactions to the mass consumer market. Since then, mobile Internet, big data, and cloud computing have continued to empower e-commerce platforms, which have evolved from commodity trading platforms to digital operation hubs, enabling innovations such as precision marketing and flexible supply chains. However, existing studies mostly focus on the value of e-commerce platforms in terms of model innovation (such as social e-commerce and live-streaming e-commerce) and market expansion. A systematic analysis has not yet been formed on the disruptive impact of e-commerce platforms on the efficiency of supply-demand matching, the reconstruction of user experience, and the reshaping of industrial ecology after the deep integration of artificial intelligence. While recommender systems remain the primary focus of AI applications in e-commerce, sentiment analysis, trust, personalization, and optimization have been identified as the field's core research themes [2].

Against the backdrop of global economic transformation, the wave of digitalization is reshaping the landscape of economic development. As a vital component of the digital economy, e-commerce has become one of the core engines driving economic growth. Electronic commerce has experienced a consistent upward trend in its significance to the global economy, a development that underscores the advantages of business digitization—specifically, how it enhances enterprises' flexibility and resilience in adapt-

ing to environmental shifts. Among the emerging trends reshaping the e-commerce landscape, the integration of AI and machine learning is particularly prominent; this is especially evident in the application of large language models, which are utilized to personalize user interactions at every phase of the customer journey [3]. With the rapid advancement of artificial intelligence technology, the operational model of e-commerce is undergoing fundamental changes. The role of artificial intelligence has become increasingly prominent, especially in such fields as data mining, precision marketing, intelligent recommendation, and supply chain optimization. Innovations in business models and science and technology have given rise to more and more cross-border innovation behaviors among platform-based enterprises. The combination of AI + e-commerce will help promote the localization of AI technology while enriching the e-commerce industry. At present, AI and e-commerce from a variety of perspectives to the depth of the combination, thus promoting the birth of new models of e-commerce, such as AI authentication, AI customer service, AI store design, AI data analysis, AI virtual anchor, etc [4]. This has not only enabled e-commerce enterprises to improve their operational efficiency but also promoted the expansion of market scale, increased national tax revenue, improved the employment environment, and optimized the allocation of fiscal resource [5].

The emergence and integration of technology into business operations have transformed workflows across diverse industries. Notably, within the e-commerce sector, pivotal technological evolutions are specifically designed to shape customer behavior, guiding their preferences toward certain products and brands. Against this backdrop, AI has emerged as an indispensable innovative tool—one that enables personalization and the customization of products to align with consumers' unique demands [6]. Breakthroughs in artificial intelligence technology have brought new variables to the development of e-commerce platforms. AI capabilities represented by machine learning, computer vision, and natural language processing are deeply penetrating the entire process of e-commerce product selection, marketing, and services. Intelligent recommendation algorithms have made “thousands of people, thousands of faces” precisely reach a norm, but they also face controversies over information cocoons; AI customer service responds 24/7 to improve service efficiency. This study focuses on the impact of artificial intelligence on e-commerce platforms, aiming to sort out the practical paths of AI technology embedding in the e-commerce ecosystem, analyze the efficiency improvements and potential challenges it brings, fill the research gap in “the evolution law of e-commerce platforms during the period of in-depth AI empowerment”, and provide empirical and theoretical support for optimizing platform operations, formulating scientific regulatory policies, and expanding

academic theories.

2. Application of AI in E-commerce

2.1 Personalized Recommendation: Precise Access Driven By Intensive Learning

While AI is rapidly revolutionizing customer service within the e-commerce sector, a notable research gap persists: its long-term effects on user behavior have not been thoroughly explored, and this is especially true for emerging e-commerce markets [7]. In the e-commerce personalized recommendation ecosystem, AI is deeply embedded in the user portrait construction and strategy optimization module, becoming an intelligent bridge connecting supply and demand. Reinforcement Learning (RL), as the core algorithm support, endows the recommendation system with the ability of „autonomous learning and dynamic adaptation“-Agent continues trial and error in the recommendation environment, and takes user behavior feedback (click, purchase, stay time, etc.) As the Reward signal. Iterative optimal recommendation strategy.

As pivotal enablers of digital transformation, e-commerce applications play a dual role: they redefine consumer behavior and drive the need for seamless online transactions, with both efforts aimed at enhancing three core aspects of e-commerce—personalization, user engagement, and adaptability [8]. In the aspect of e-commerce personalized recommendation, it should be accurately anchor the pain points of e-commerce recommendation: traditional algorithms rely on static historical data, which is difficult to capture the drift of user interest (such as the short-term interest outbreak of sudden attention to outdoor equipment), and easy to fall into the „information cocoons“ (excessive push of familiar categories, restricting consumption exploration). Personalized recommendation for e-commerce, a reinforcement learning framework is introduced, and the recommender system is defined as an agent to analyze user behavior rewards in real time: when the recommended content triggers high clicks and cross-category browsing, the agent obtains positive incentives; otherwise, the agent adjusts the strategy. Static adaptation approaches lack real-time flexibility, whereas generative AI stands out by enabling adaptive interactions that occur in real time and are tailored to individual needs—thus creating a user experience that is far more engaging and adaptable [8].

In the three integrated e-commerce platforms of Alibaba, Jingdong and Tik Tok, the information of the three platforms is integrated, and it is found that the click-through rate of recommendation can be increased by about 30% and the richness of user browsing categories can be increased by about 35% by integrating the information of the three platforms through AI intervention in the person-

alized recommendation of e-commerce. Through AI to learn the user's shopping needs, to achieve a dynamic balance between „accuracy“ and „diversity“, not only to meet the user's dynamic needs (such as the sudden increase of gift search before the festival into accurate recommendation), but also to guide consumer exploration, thereby enhancing the exposure of minority categories and reshaping the value of the recommendation system.

2.2 Supply Chain Optimization: Full Link Intelligence from Inventory to Logistics

2.2.1 Inventory Optimization: The „Digital Brain“ of Dynamic Balance

AI-driven inventory management breaks through the traditional experience decision-making mode and constructs a „data + forecast + dynamic control“ system. Machine learning algorithms integrate multi-source data: historical sales curves (distinguishing seasonal fluctuations and hot sales cycles), social public opinion (online celebrities bringing goods, bad reviews warning), and even weather data (rainy season affects outdoor equipment sales). Taking FMCG e-commerce as an example, the AI model predicts the peak demand of „the same style of Internet celebrity“ 7-14 days in advance, and links up suppliers to stock up flexibly; for unsalable goods, it identifies „bad evaluation correlation characteristics“ (such as products with concentrated quality complaints) through clustering analysis, and triggers inventory clearance instructions. Through this method, the inventory turnover rate can be improved, the proportion of unsalable inventory can be reduced to a certain extent, more funds can be used for new product development, and the double breakthrough of „cost reduction + efficiency enhancement“ in the supply chain can be achieved.

2.2.2 Transportation Route Optimization: „Path Revolution“ of Dynamic Game

In the process of logistics distribution, AI integrates operations research and in-depth learning to solve the problem of „multi-constraint path planning“. The system accesses real-time traffic data (congested road sections, accident warning), order characteristics (weight and volume, delivery timeliness requirements), site distribution (density and coverage radius), and constructs a dynamic programming model. During the morning rush hour, the algorithm preferentially recommends the „outer ring of the city + community connection“ route to avoid congestion in the core area; the hierarchical strategy of „centralized distribution center → micro site → last kilometer“ is adopted in the order-intensive area. Under the prediction of AI model, AI planning route can reduce vehicle mileage by 25% and increase the punctuality rate of distribution by about 15%. On one hand, the surge in e-commerce and rising demand

for same-day delivery have sharply boosted the need for efficient last-mile logistics. On the other hand, traditional vehicle routing methods fall short: they struggle to handle real-world constraints such as traffic congestion, energy shortages, and dynamic changes in delivery demands [9]. If regional fresh e-commerce can access AI planning, through dynamic balance of „cost, timeliness and experience“, it can not only reduce logistics losses (cold chain transportation path optimization can reduce certain corruption), but also strengthen user satisfaction and reshape the „last mile“ value of supply chain.

2.3 Fraud Detection: An Intelligent Guard for Transaction Security

In the current digital age, fraud detection has grown progressively more important, where large-scale transactions are processed in real time, posing challenges for conventional detection methods. Big data is proliferating in financial systems, and this has made analyzing massive, high-dimensional datasets more complex. As a result, advanced techniques are needed to ensure fraud detection is accurate and timely [10].

Traditional methods are becoming increasingly ineffective as fraudsters adapt their strategies, the above situation emphasizes that more sophisticated solutions are essential. Given the demand for real-time fraud detection, AI-driven tools—such as machine learning algorithms and big data analytics—have become indispensable, as they significantly improve both efficiency and accuracy. Critically, fraudulent patterns are not static; their continuous evolution means AI-powered detection systems must also adapt on an ongoing basis [11].

On the one hand, e-commerce enables global trade in goods and services, delivering tangible benefits—convenience and accessibility—to both consumers and businesses. On the other hand, its inherent vulnerability to fraud cannot be ignored, as malicious transactions pose considerable risks to all involved parties [12]. In e-commerce transactions, fraudulent acts such as false transactions, malicious bill-brushing and account theft directly threaten the platform ecology and user trust. AI relies on the system of „abnormal pattern recognition + real-time wind control“ to build a line of defense for transaction security. By analyzing the user behavior baseline (normal transaction frequency, device fingerprint, IP geographic features), the machine learning model captures anomalies in real time: large transactions in different places in a short time, frequent attempts to pay by multiple devices, and centralized scalping of new registered accounts, all of which trigger the closed-loop response of „risk scoring → verification process → interception decision“. Comprehensive data from several cross-border e-commerce platforms show that after the introduction of AI fraud de-

tection system, the interception rate of false transactions can be increased by about 25%, and the loss of theft can be reduced by three quarters. More importantly, through the continuous iteration of „semi-supervised learning“, the algorithm identifies new fraudulent means (such as using AI to generate false transaction vouchers), guarantees the reputation of the platform and the security of users' property, and builds an „intelligent firewall“ for the e-commerce ecology.

From the „demand insight“ of personalized recommendation to the „efficiency reconstruction“ of supply chain to the „security guard“ of fraud detection, AI has deeply penetrated the whole link of e-commerce. In the future, with the integration of large models, edge computation and other technologies, AI will further break through the „data island“ and „scene boundary“, and drive e-commerce to evolve to „intelligent decision-making, ecological collaboration, and extreme experience“-this is not only a technological iteration, but also a profound change in reconstructing the value logic of the industry, so that e-commerce can truly achieve „intelligent empowerment, quality and efficiency“ Sustainable development.

3. Discussion

3.1 Limitations and Challenges

The complexity of managing personal information in a big data environment requires e-commerce organizations to adopt strong data protection measures to safeguard individual privacy rights and ensure ethical practices. However, as ai participates in the operation of e-commerce platforms, and with the continuous growth of data volume and the acceleration of data flow, traditional security measures have been difficult to meet the demand, and ai's data protection also has a certain problem [13].

3.1.1 Data security risks

The deep application of AI in e-commerce is inseparable from the collection and analysis of massive user data, which includes personal information, consumer preferences, payment records and other sensitive content. However, the technical loopholes of AI system itself and the imperfection of platform data protection mechanism may lead to the risk of data leakage. Once an information security incident occurs, it will not only violate the privacy of users, but also cause a crisis of trust, which will have a negative impact on the long-term operation of the platform. More noteworthy is the „pollution“ of AI training data. In order to obtain improper competitive advantage, some businesses create false transaction data through informal means, which will distort the recommendation logic after being learned by AI algorithm, resulting in the burial of high-quality goods and the acquisition of false informa-

tion by users, thus destroying the fairness and health of the whole e-commerce ecosystem.

3.1.2 The algorithmic bias dilemma

The AI recommendation algorithm of e-commerce platform is mainly based on the user's historical behavior data to build consumer portraits, and then match the goods. However, this model is prone to bias: due to the lack of behavior data for new users, the algorithm is difficult to accurately capture their needs, and can only push popular products, so it is difficult to obtain personalized experience; due to the lack of data samples for the corresponding products, the algorithm can not effectively identify the preferences of minority users, and they are covered by mainstream products for a long time, so it is difficult to access the categories that meet their needs.

From the business dimension, the algorithm is naturally inclined to the head brand. Head merchants accumulate a large number of positive data with mature operation system, so AI algorithm will form path dependence and direct more traffic to these brands, while small and medium-sized merchants, even if the goods are of good quality and distinctive features, may be „neglected“ by the algorithm due to insufficient initial data accumulation, and face difficulties in promotion and high cost of customer acquisition. To a certain extent, this limits the diversity and innovation vitality of e-commerce ecology.

3.2 Future Prospects

In the future, in view of the potential problems of data security, the platform should increase investment in technology research and development, use end-to-end encryption technology to encrypt the whole life cycle of user sensitive data, and introduce AI intrusion detection system to monitor abnormal data access behavior in real time. Establish a hierarchical data management system, classify personal information and payment records as highly sensitive data, restrict access rights and retain operation logs. Regularly carry out security vulnerability investigations, conduct penetration testing with third-party security agencies, and timely repair the technical defects of AI system. Aiming at the problem of algorithm bias, the platform should establish a dynamic evaluation system, which not only refers to historical data, but also incorporates commodity innovation and user repurchase rate into the assessment, so as to avoid the path dependence of the algorithm on the head brand. Publicize the core logic of algorithm recommendation rules regularly, accept the supervision of industry associations and users, and ensure the diversity and innovation vitality of e-commerce ecology. To achieve two key goals—designing standardized, reliable product quality control methods and exploring new customer outreach and service models at low cost—the e-commerce and financial industries have deployed AI.

This technology has in turn helped them enhance customer experience, optimize supply chain management, improve operational efficiency, and reduce expenses [14]. In the future, with the integration of large models, edge computation and other technologies, AI will further break through the “data island” and “scene boundary”, and drive e-commerce to evolve to “intelligent decision-making, ecological collaboration, and extreme experience”—this is not only a technological iteration, but also a profound change in reconstructing the value logic of the industry, so that e-commerce can truly achieve “intelligent empowerment, quality and efficiency” Sustainable development.

3.2.1 Full-link intelligent upgrade

In the future, AI will deeply penetrate the whole process of e-commerce and realize the intelligent remodeling of the whole link from front-end customer acquisition to back-end supply chain. In the selection process, AI will combine multi-dimensional information such as market trend analysis and consumer feedback interpretation to accurately predict potential hot commodities and help businesses plan inventory and marketing strategies in advance. In the logistics link, AI dispatching system will realize „global intelligence“, optimize the distribution path and order independently based on dynamic information such as real-time road conditions, warehouse inventory and order distribution, and monitor the storage environment and transportation status in real time with the technology of Internet of Things, warn and deal with abnormal situations in time, so as to promote the efficiency and stability of distribution. Let efficient distribution become the norm of the industry.

In the after-sales scenario, AI customer service will break through the traditional voice response mode, identify the emotional state and demand urgency of users during consultation with the help of emotional analysis technology, quickly access the full link information of transactions, and give reasonable solutions. For complex problems, it can automatically transfer manual customer service and synchronously preprocess content, greatly improve the efficiency of problem solving, and enhance user stickiness.

The vast majority of services and transactions can be carried out through the Internet, such as Taobao and Jingdong. Nevertheless, the synergy between robots and channelized voice service centers offers significant potential to optimize two key aspects of voice services: quality enhancement and cost reduction. Concurrently, through the research and development of natural language technologies, an intelligent and centralized mobile communication service application platform has been constructed with the WeChat platform as its foundation. Furthermore, by leveraging technological advancements in natural language processing, machine learning, and big data computing, the project prioritizes the application of online robots—

specifically, using them to identify and comprehend customer problems, and provide timely feedback on customer requirements.

3.2.2 Virtual and real fusion experience

Driven by AI technology, e-commerce consumption scenarios will break the fragmentation of online and offline, and move towards a new form of “virtual and real integration”. Virtual try-on technology will be more mature, through 3D modeling and motion capture technology, users can try on clothes and accessories in virtual space in real time, and simulate the wearing effect in different scenes, intuitively feel the upper body state of goods. AR shopping guide will be deeply integrated into the physical consumption scenario, consumers through mobile devices to scan goods, you can get component analysis, user evaluation, collocation suggestions and other information, to achieve seamless connection between offline experience and online data.

4. Conclusion

With the continuous breakthrough and high-speed iteration of artificial intelligence technology, the cross-border e-commerce industry has entered a new stage of development driven by AI. This technology is reshaping the ecosystem and business chain of cross-border e-commerce with unprecedented penetration, and accelerating the evolution of the whole industry towards a more efficient and intelligent direction.

The application of AI in the field of e-commerce not only faces practical challenges such as data security and algorithm bias, but also shows the potential of reshaping the industry pattern due to the development of full-link intelligent upgrade and virtual-real integration experience. With the deep penetration of AI into the whole process of e-commerce, the industry will achieve a double breakthrough in efficiency and experience from the precise prediction of product selection, intelligent scheduling of logistics to the integration of virtual and real consumption scenarios. This will not only bring more convenient and immersive shopping experiences to consumers, but also create a fairer development environment for small and medium-sized businesses, and promote e-commerce from traffic competition to value creation. In the future, AI-driven e-commerce ecology will continue to break through the boundary and iterative mode, and become the core driving force of consumption upgrading in the digital

economy era.

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