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The Application of Artificial Intelligence in the Analysis of Criminal Evidence

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Abstract
With the rapid advancement of technology and the strengthening trend of the integration of artificial intelligence with the judicial system, its application in the field of criminal evidence has become a prominent topic of interest. The application of artificial intelligence in the analysis of criminal evidence holds significant importance. It not only helps reduce the burden on judicial personnel and increase their efficiency amid the rising number of cases, but also plays a prominent role in preventing wrongful convictions and safeguarding procedural justice. Moreover, it is feasible at both the policy and practical levels. However, its application also faces numerous challenges, such as the difficulty in simulating human irrational thinking, deficiencies in deep learning algorithms, and the potential to trigger conflicts of interest and real-world risks. To address these issues, several strategies can be explored, such as reasonably limiting the scope of artificial intelligence applications, adhering to the principles of assistance, limitation, and refutability, enhancing the support of authoritative judicial data, improving algorithm transparency and interpretability, appropriately strengthening the rights of the accused, and balancing criminal prosecution with the protection of human rights. Through these measures, the aim is to harness the advantages of artificial intelligence, ensuring judicial fairness and efficiency while avoiding the abuse of technology and the emergence of risks, thus achieving the goal of empowering the judiciary with technology.

Keywords
Artificial Intelligence; Criminal Evidence; Judicial Application; Evidence Analysis

1 Introduction

After decades of development, artificial intelligence (hereinafter referred to as "AI") has made remarkable achievements in fields such as big data, cloud computing, deep learning, and natural language processing. In 2022, The Supreme People's Court of the People's Republic of China issued the "Opinions on Regulating and Strengthening the Judicial Application of AI," aiming to promote the deep integration of AI with judicial work and build an intelligent auxiliary system. In 2024, Zhang Jun, President of the Supreme People's Court of China and Chief Justice, spoke at the 19th Asia-Pacific Chief Justices' Conference, pointing out the importance of strengthening multilateral cooperation platforms in fields such as AI. He also emphasized that the Chinese courts will continue to explore the use of AI technology to empower the judiciary. In early 2025, the DeepSeek-R1 series models was launched, attracting global attention with its superior data processing, image recog-

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nition, and intelligent decision-making capabilities. Government systems and judicial authorities in various regions, including Beijing, Hebei, and Guangdong, have already started experimenting with the application of AI tools to assist with office operations. The trend of empowering judicial work with AI is becoming an inevitable development.

The integration of AI with criminal evidence has become a topic of widespread attention in both academic and practical circles. Its application in the analysis of criminal litigation evidence is a multidimensional issue, involving the deep integration of modern technology, legal ethics, and judicial practice. This not only demonstrates significant potential for judicial progress but also comes with various risks and challenges, which require careful consideration. The existing research on this topic mainly focuses on three aspects: first, the application value of AI in the collection, examination, and evaluation of criminal evidence; second, the role of AI in the aforementioned tasks; and third, the limitations of AI in criminal evidence analysis and the countermeasures.

In China, academic research on the application of AI in criminal evidence analysis mainly focuses on the collection, examination, and evaluation of evidence. Scholars believe that AI can improve the discovery and utilization rates of physical evidence, increasing the likelihood of obtaining information needed for investigations; and help judicial personnel quickly grasp the norms for investigating cases and the rules for obtaining and using evidence under the guidance of a digitized and unified evidentiary standard, regulating investigative practices. AI can also examine the "three characteristics"[1]of evidence obtained during an investigation, preventing flawed and illegal evidence from entering the trial stage. Additionally, it offers greater efficiency, accuracy, and advantages in helping to restore the facts in the review of electronic evidence. What's more, AI can assess, based on statutory standards, whether criminal evidence possesses competency of evidence from a formal perspective[2],and evaluate the probative value of the evidence. Regarding the role of AI in criminal evidence analysis, scholars generally believe that it should serve as an auxiliary tool in judicial practice. Some scholars advocate that AI should only perform a formal screening of evidence based on its appearance, while others believe that the application of AI should evolve from evidence-guided functions in a formal or procedural sense to proof-assisting mechanisms that contribute to the substantive evaluation of facts. However, both them maintain the view that human beings must remain the ultimate decision-makers in judicial proceedings. Regarding the limitations of AI in criminal evidence analysis and the corresponding solutions, scholars have conducted research from various perspectives, including evidence standards, algorithmic weaknesses, and the risks of infringement. Introducing AI technology into the field of criminal evidence may strengthen reliance on statutorily prescribed evidence types, thereby weakening the principle of free evaluation of evidence. Moreover, issues such as the uncertainty of data algorithms, threats to privacy, and technological monopolies are also causes for concern. Therefore, some scholars propose that the application of AI in criminal evidence analysis should adhere to the principle of risk prevention and comply with ethical and moral guidelines. From this perspective, existing research has conducted relatively macro-level discussions on the application, positioning, limitations, and improvements of AI in criminal evidence analysis, but further research is needed at the micro-level.

1 In China, the "three characteristics" of criminal evidence refer to the fundamental attributes that evidence must possess: objectivity, relevance, and legality. Specifically, evidence must objectively reflect the facts of the case, have a logical connection to the facts to be proven, and be collected and presented in compliance with legal procedures.

2 In the context of Chinese criminal procedure law, the concept of "zheng ju neng li," often translated as "competency of evidence," refers to the legal qualification of evidence materials to enter the court investigation process and serve as a basis for fact-finding. It is primarily assessed based on three fundamental attributes: objectivity, relevance, and legality.

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In foreign practice, the utilization of AI is reflected in assisting judicial evidence analysis and the review of expert testimony, with scholars also recognizing its auxiliary value. British scholars have proposed the use of intelligent decision support systems to address deficiencies in the work of the Crown Prosecution Service. For instance, artificial neural networks with machine learning capabilities can identify and classify evidence, uncovering relationships between variables that are not easily discernible by humans, thereby demonstrating potential value in evidence analysis. In the United States, AI is commonly used as an auxiliary tool to assist judges in determining the admissibility of evidence such as expert testimony, particularly when judges lack familiarity with certain area. This aids in bridging their knowledge gaps and enhances the compliance and scientific rigor of evidence evaluation and determination. While countries around the world acknowledge the significance of applying AI to judicial evidence processing and have begun to implement it in practice, the prevailing viewpoint remains cautious regarding the introduction of it into the realm of criminal adjudication. It is widely held that AI cannot replace the role of judicial personnel and should maintain its auxiliary status, with humans continuing to play the dominant role in judicial decision-making.

This article will analyse the current state of practice regarding the application of AI in criminal evidence analysis, using classic cases from recent years before and after the introduction of AI as references. The aim is to propose improvements to ensure judicial fairness and efficiency while preventing technological misuse and associated risks.

2 The Rationality of Applying AI in Criminal Evidence Analysis

The application of AI in the field of criminal evidence analysis facilitates the efficient handling of complex and voluminous evidence materials, alleviating the judicial burden amid a surge in cases. It also holds legitimate value in preventing wrongful convictions and upholding procedural justice. Moreover, this application is supported by current policies and practical foundations, indicating a high degree of feasibility.

2.1 Enhancing Efficiency: Leveraging AI to Alleviate Judicial Workload Amidst Rising Caseloads

Amid the rapid advancement of the society, the demand for legal services has grown at an unprecedented rate. Data from the Supreme People's Court's year-end work reports from 2019 to 2023, the number of cases accepted by local courts at all levels has exhibited a consistent upward trajectory, with a marked surge in 2023—a 15.6% year-on-year increase. However, the training and supply of legal professionals have not kept pace with this growing demand, resulting in a persistent imbalance between caseloads and available judicial personnel. Judges and other legal practitioners often operate under significant strain, facing a chronic "more cases, fewer personnel" dilemma. It is therefore imperative to employ AI technologies in a rational and targeted manner to address tedious and repetitive tasks, alleviate the non-essential workload of judicial personnel, and reallocate adjudicative resources toward more substantive functions such as the analysis of factual and legal issues at the heart of each case.

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The examination and evaluation of criminal evidence constitute a central component of the judicial adjudication process, playing a decisive role in determining a defendant's culpability and the appropriate sentencing. However, the analysis of criminal evidence often involves massive volumes of information, intricate data structures, and complex chains of reasoning, making traditional manual methods time-consuming, labor-intensive, and prone to error. In light of these challenges, the integration of AI technologies in the processing of criminal evidence demonstrates clear comparative advantages. AI can assist in the efficient classification, synthesis, and relational analysis of evidentiary materials, thereby providing legal professionals with a clearer and more systematic framework for understanding the case. This, in turn, facilitates a more comprehensive grasp of the case as a whole and its underlying logic. Such applications hold significant potential for enhancing judicial efficiency and conserving judicial resources. In Britain, the Avon and Somerset Police, using a AI tool called Söze, analyzed evidentiary materials in complex cases. Evaluation results indicate that while traditional manual methods would require several decades to review the relevant data, Söze completed that within 30 hours. The Chair of the National Police Chiefs Council emphasized that AI holds tremendous potential in unsolved cases involving voluminous and intricate evidence.

Guizhou Province has developed the Guiyang Political and Legal Big Data Case-Handling System, which encompasses functions such as the generation of electronic case files, verification of evidence, and review of evidentiary chains. It facilitates cross-departmental collaboration among public security organs, procuratorates, and courts through the integration of big data, thereby significantly enhancing judicial efficiency and offering a practically viable model for reference. Designed to meet the functional mandates and operational needs of the police, procuratorates, and courts, the system establishes a standardized workflow for case handling. Leveraging AI and data visualization technologies, it constructs a comprehensive evidentiary data chain and enables intelligent review and circulation of evidence, both in terms of its existence and its integrity. The assistance of AI systems can help judicial personnel optimize case-handling procedures and reduce potential omissions during evidence collection or the drafting of legal documents, thereby improving overall work efficiency. In future judicial practice, the rational application of AI technologies is expected to become a key driving force in enhancing both the efficiency of judicial personnel and the timeliness of case resolution.

2.2 Practical Value: The Dual Role of Artificial Intelligence in Criminal Evidence Analysis

On the one hand, the application of AI in the analysis of criminal evidence contributes to the prevention of wrongful convictions. At its core, the occurrence of such miscarriages of justice stems from errors in the collection, examination, and evaluation of evidence. These errors often result in evidentiary flaws and factual ambiguities, which in turn lead to incorrect court decisions and severely undermine the integrity of justice. For instance, in the case of Huugjilt, he was prosecuted by the Hohhot People's Procuratorate of Inner Mongolia for the crimes of intentional homicide and hooliganism. He was subsequently sentenced to death at first instance by the Hohhot Intermediate People's Court, a verdict that was upheld and approved upon appeal. However, during retrial proceedings, the court identified serious errors in the evidentiary basis for both conviction and sentencing. These included inconsistencies between the defendant's confession

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and the forensic autopsy report, instability in his self-incriminating statements, numerous contradictions between his confession and other pieces of evidence, and a complete lack of corroborating evidence to support the original conviction for hooliganism apart from his own confession. Despite these significant flaws, the deficiencies in the evidentiary record were not adequately considered by the case-handling personnel. As a result, the trial court delivered a hasty judgment in the absence of clear facts and sufficient evidence, ultimately leading to a grave miscarriage of justice. Therefore, the prevention of wrongful convictions must be centered on the proper handling and evaluation of evidence. Unlike human intelligence—which is susceptible to subjectivity, including negligence, bias, and empiricism—in the process of evaluating criminal evidence, AI can, through deep learning capabilities, apply a more objective approach by using the "three characteristics" of evidence as the standard for review and verification. AI can assist in identifying evidentiary issues at various stages of the criminal process. For instance, during the investigative phase, AI systems can provide prompts and verification mechanisms to guide investigators in determining which forms of evidence meet the evidentiary thresholds required in criminal procedure. They can also monitor the legality of evidence collection and exclude materials that fail to meet statutory standards. In the trial phase, both the prosecution and the defense may use AI tools to present and challenge evidence, while judges can utilize big data technologies for evidence comparison and precedent retrieval, thereby promoting consistency in case adjudication. Moreover, AI can help circumvent the fallacy of "selective evidence confirmation," reducing the risk that subjective tendencies of Judicial personnel might improperly influence the direction of a case. In sum, the application of AI in the criminal justice field not only helps prevent the omission of legally admissible and effective evidence, but also acts as a safeguard against the introduction of "tainted evidence" into legal proceedings. This significantly enhances the scientific, rational, impartial, and objective assessment of criminal evidence, thereby serving as a critical measure in preventing wrongful convictions.

On the other hand, the application of AI in criminal evidence analysis can serve to uphold procedural justice. The key to achieving procedural fairness in criminal proceedings lies in the ability to visualize the processes of evidence collection, review, and evaluation. When applied to the analysis and verification of criminal evidence, AI can significantly enhance the transparency of judicial procedures and ensure the legality and regularity of judicial conduct. A representative example is the Shanghai Intelligent System for Criminal Case Handling Assistance (hereinafter referred to as "Shanghai 206 System") developed by the Shanghai High People's Court, which reflects how AI can standardize judicial procedures and regulate evidentiary assessment in criminal cases while compelling judicial personnel to strictly adhere to procedural requirements. The system integrates unified evidentiary standards into a data-driven workflow systerm and offers guidance on the construction of evidentiary chains for various categories of typical cases. In addition, it includes comprehensive standards for evidence review, covering normative elements such as the content and form of evidence, the procedures for its collection, and the rules for exclusion. This system effectively compels judicial actors at all stages, including investigation, prosecution, and adjudication, to comply rigorously with legally prescribed procedures. For instance, in the scenario where a public security authority submits a case for prosecutorial review, once the case file is entered into the system, the AI conducts an intelligent audit of the materials. If it detects that a particular category of evidentiary material is missing, the system will generate an alert and prompt the user to supplement the record. Therefore, the integration of AI

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into criminal evidence analysis can help reduce the arbitrariness of judicial decision-making, ensure procedural compliance, and enhance the accuracy of evidentiary evaluation. In doing so, it enables the outcomes of evidentiary assessments to withstand scrutiny under the standards of procedural justice, while also aligning with the broader expectations of substantive justice.

2.3 Feasibility Analysis: Policy and Practical Foundations

The application of AI to criminal evidence analysis is practically feasible at the policy level. China has attached great importance to the integration of AI technologies into the judicial field and has issued a series of supportive and regulatory policies. In 2017, the State Council of China released the "New Generation Artificial Intelligence Development Plan," which explicitly called for the establishment of "intelligent courts" and the promotion of AI applications in evidence collection, case analysis, and legal document reading and interpretation. The plan aims to achieve the intelligentization of court adjudication systems and capabilities, thereby providing clear direction and policy guidance for the use of AI in criminal evidence analysis. In 2019, the Supreme People's Court of China issued the "Fifth Five-Year Reform Outline of the People's Courts (2019-2023)," which proposed the full utilization of modern technologies such as big data, cloud computing, and AI to address reform challenges, enhance judicial efficiency, and jointly advance judicial reform alongside the development of intelligent and information-based courts. The Outline affirmed that AI, through its powerful data processing and analytical capabilities, can support the modernization of adjudicatory systems and capacities. Given that evidence analysis is a critical component of judicial adjudication, it is a natural and essential domain for the implementation of AI tools. In 2022, the Supreme People's Court of China issued the "Opinions on Regulating and Strengthening the Application of Artificial Intelligence in the Judiciary," which articulated the overarching goal of "smart court" construction as fostering deep integration between AI technologies and judicial functions, thereby providing a higher level of digital assurance for justice that serves the people and ensures fairness. This document offers a clear policy orientation for the application of AI in criminal evidence analysis. In 2023, the Supreme People's Procuratorate of China released the "2023-2027 Prosecutorial Reform Work Plan," which emphasized the need to "establish and improve mechanisms for digital prosecution, actively construct a prosecution model characterized by 'business-led, data-integrated, technology-supported, and application-oriented' operations, and innovate methods of prosecutorial oversight under big data conditions." This framework creates a more supportive operational environment and data foundation for AI-assisted criminal evidence review and evaluation. Moreover, while there is currently no specialized legal provision specifically governing the application of AI to criminal evidence analysis, the existing legal and regulatory framework is, to a certain extent, capable of accommodating and regulating such applications. For instance, the "Cybersecurity Law of the People's Republic of China" contains provisions on the protection of personal information, which can be applied to safeguard the security of network data involved in the collection and analysis of evidence, preventing the unlawful acquisition, tampering, or disclosure of evidentiary data. In addition, the "Provisions on Several Issues Concerning the Collection, Extraction, Examination, and Evaluation of Electronic Data in Handling Criminal Cases" set forth specific rules governing the collection, review, and evaluation of electronic evidence. These provisions provide critical normative guidance for the use of AI in handling electronic criminal evidence, thereby ensuring the legality and regulatory compliance of AI-assisted evidence analysis.

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The application of AI in criminal evidence analysis is also grounded in a solid foundation of practical implementation. Across China, judicial authorities in various regions have actively explored the use of AI in this domain and have achieved notable results. In addition to the aforementioned Shanghai "206" System and the Guiyang Political and Legal Big Data Case-Handling System, another representative example is the "Jiandu" Smart Prosecution System developed by the People's Procuratorate of Qingyuan City in Guangdong Province. The Shanghai "206" System, in particular, plays a key role in supporting evidence collection. It establishes evidentiary standards tailored to common offenses encountered in local criminal cases and offers clear, standardized guidance for legal practitioners on the categories of evidence that should be collected at various procedural stages. The Guiyang Political and Legal Big Data Case-Handling System translates evidentiary guidance rules into mathematical models, enabling intelligent computation to assess the completeness of criminal evidence. This process places normative pressure on investigative authorities to collect evidence in a standardized and lawful manner. The system also automatically filters compliant evidence and intercepts cases with evidentiary flaws. Meanwhile, the "Jiandu" Smart Prosecution System relies primarily on intelligent technologies such as Optical Character Recognition and Natural Language Processing. It performs intelligent recognition and classification of electronic case files in criminal matters. The system initiates procedural reviews of evidence, annotates factual elements, assesses evidentiary relevance and probative value, and even supports sentencing prediction. As such, it provides prosecutors with comprehensive and detailed assistance in criminal evidence analysis, significantly advancing the intelligent development of this field.

In conclusion, the application of AI to the analysis of criminal evidence demonstrates significant feasibility at both the policy and practical levels. From a policy perspective, a series of national and judicial initiatives have provided clear direction and institutional support for such applications, while the existing legal framework ensures their operation within a legitimate and compliant scope. In practice, judicial innovations in regions such as Shanghai, Guiyang, and Qingyuan have yielded fruitful results. Intelligent systems have played a vital role in key processes such as evidence collection and evaluative judgment. These experiences offer valuable reference points for judicial authorities across the country seeking to deploy AI tools to enhance the efficiency and precision of criminal evidence analysis.

3 Existing Challenges in the Application of Artificial Intelligence to Criminal Evidence Analysis

Despite the numerous advantages and high degree of feasibility associated with the application of AI in criminal evidence analysis, its implementation in practice still faces significant challenges. These challenges fall primarily into three categories: Firstly, AI struggles to replicate uniquely human forms of irrational thinking, which are essential to the process of evidence assessment and the formation of judicial conviction. Secondly, flaws in deep learning algorithms can compromise the accuracy of evidentiary judgments and even lead to wrongful convictions, thereby undermining judicial fairness. Thirdly, the use of AI in judicial proceedings raises concerns about diminishing the autonomy of judicial personnel and restricting the rights of the defense.

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3.1 Preserving Human Reasoning: The Inability of Artificial Intelligence to Simulate Human Irrationality

Article 55 of the Criminal Procedure Law of the People's Republic of China defines the standard of proof as requiring evidence to be "genuine and sufficient," reflecting the pursuit of a unified objective and subjective truth in criminal adjudication. With rapid advancements in technology, AI has become capable of addressing the objective dimension of evidence. For instance, intelligent judicial assistance systems in cities such as Shanghai and Guiyang can list the types of evidence required for different categories of cases, provide procedural guidelines for various stages of litigation, and assist in verifying the authenticity of evidence. However, significant difficulties remain in achieving the subjective aspect of this standard, particularly in forming judgments "beyond a reasonable doubt." One prominent limitation is AI's inability to simulate the uniquely human capacity for irrational or intuitive reasoning.

According to the theory of Daniel Kahneman, a world-renowned psychologist, judicial decision-making typically begins with intuitive judgments, and such intuitive conclusions are often remarkably accurate. Subsequently, judicial personnel use rational, logical analysis to verify and refine these initial intuitions. From both cognitive and practical perspectives, these two modes of thinking can be understood as "irrational thinking" and "rational thinking". Judicial activities involve not only rational processes such as logical reasoning and legal deduction, but also rely on irrational elements such as intuition, emotion, and experience of legal practitioners. For example, in the trial of Zhao Chunhua, who was charged with illegal possession of firearms, a purely rational assessment of the legal elements could easily lead to a rigid and mechanical conclusion that she had committed the crime of illegal possession of firearms, and should be sentenced to three to seven years in prison. However, when taking a more holistic approach that incorporates irrational thinking, it becomes evident that Zhao's intent was to operate an amusement-oriented shooting stall, and that the firearms in question used plastic bullets. Her subjective malignancy and the potential danger to personal safety were both relatively low, and the overall social harm of her conduct was limited. The first-instance sentence was therefore disproportionately harsh and misaligned with both reason and sentiment. This example illustrates that rational and irrational thinking exist in dialectical unity within human cognitive activity, and both are indispensable to the process of judicial adjudication.

In assessing criminal evidence, judicial personnel must synthesize rational deductions based on objective facts with elements of irrational thinking, such as experience, emotion, and value judgments, to form "inner conviction" thereby reaching a conclusion that meets the standard of "beyond a reasonable doubt." The essence of using AI to evaluate criminal proof standards lies in simulating human cognitive processes. While AI can emulate rational thinking through the aggregation of rule-based simulations, irrational human thought is complex, non-rule-based, and inherently illogical. As such, it cannot be identified or executed through algorithms, nor can it be effectively simulated through any simple set of rules. Moreover, AI struggles to incorporate human experience into its assessments. This is because human experience is vast in scope and extremely difficult to encode in a logical language intelligible to machines. Even with the aid of big data and deep learning capabilities, AI faces limitations: human experience evolves over time and varies across industries, regions, and cultural norms. The same experience may carry different implications

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in different contexts. Some value judgments may even "be masked," making them difficult to discern. For example, in specific contexts, humans can easily understand the true intention behind a "white lie," whereas AI may only interpret its literal meaning. Therefore, when it comes to applying irrational thinking in the assessment of criminal proof standards, AI remains relatively disadvantaged. Its role is more auxiliary and indicative, while the final judgment must rely on the subjective discernment of judicial personnel, informed by their individual experience, intuition, and emotional intelligence.

3.2 Bias in Foundational Inputs: Practical Limitations of Deep Learning Algorithms in Evidence Review

The core of AI's role in criminal evidence evaluation lies in its algorithmic foundation. At present, the dominant algorithmic model in the AI field is the deep neural network, which excels in autonomous and associative learning, enabling it to simulate human cognition in the analysis and assessment of criminal evidence. However, several persistent challenges hinder its practical application in judicial contexts, and the most notably issues relate to data quality and the "black box" nature of algorithms. These difficulties can significantly compromise the accuracy of AI-generated evidentiary assessments, thereby affecting case outcomes.

Firstly, the quality of the data on which AI operates is highly inconsistent. Data samples are essential for training AI algorithmic models, and the richness, accuracy, and authenticity of such samples have a decisive impact on AI's capacity for criminal evidence evaluation. In China, the data resources available for AI-assisted criminal evidence assessment primarily include laws and regulations, judicial interpretations, and publicly accessible court decisions, chiefly those published on China Judgments Online, the official platform for court judgment disclosure, as well as unpublished decisions from local courts. However, when used as training samples for deep learning algorithms, these data present concerns regarding both quality and quantity. On the one hand, publicly available judicial data is characterized by its superficiality, in that the information disclosed to the public is often compiled according to specific standards intended to demonstrate the correctness of legal decisions. As such, it may fail to authentically and comprehensively reflect the substantive information upon which judges actually based their rulings. These forms of "secondary data" may omit or obscure the actual facts and evidentiary materials of the case to some extent and are often incapable of capturing the judge's subjective discretion grounded in non-rational thinking processes. Moreover, the quality of data samples may also be compromised during the process of transforming raw data into machine-readable, annotated datasets. This is because data annotation essentially involves the conversion of "raw data" into "training data," typically through a combination of automatic and manual annotation. At present, the development of natural language processing technologies in the legal field remains relatively limited, resulting in low accuracy in AI-driven information extraction. Manual annotation, on the other hand, requires a high level of domain-specific expertise. Many legal terms cannot be accurately labeled based on general knowledge alone, and annotators may, to varying degrees, inject their own subjective interpretations during the labeling process, further exacerbating inconsistencies in the quality of case data samples. On the other hand, the development of China Judgments Online is relatively recent, and a large portion of historical judicial data has not been included. This absence of historical data is detrimental

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to the deep learning processes required by AI systems. Moreover, the volume of data samples currently available to AI falls far short of the "massive scale" necessary for effective deep learning, especially in the case of rare or sensitive cases such as death penalty trials, where available samples are extremely limited. In addition, the court decisions published on the China Judgments Online exhibit a marked degree of regional disparity; courts in more developed regions disclose far more decisions than those in less developed areas. In summary, data samples are foundational to AI-based deep learning. However, the current samples suffer from inherent temporal and spatial deficiencies, either due to "congenital insufficiencies", such as historical gaps, or "acquired malnutrition", such as insufficient quantity or quality. Such limitations significantly undermine the accuracy and reliability of AI applications in the judicial field. Therefore, improving both the quality and quantity of judicial data samples remains an urgent and pressing challenge.

Secondly, the algorithms upon which AI operates face the problem of the "algorithmic black box," which runs counter to the principles of judicial transparency and fairness. The "algorithmic black box" represents another major challenge in applying AI to the field of criminal evidence analysis. This concept refers to certain aspects of an algorithm's operation being too complex to understand due to technical intricacies. In the context of criminal evidence analysis, it manifests as a lack of transparency and openness in the process of evidence evaluation and reasoning. The public remains unaware of the algorithm's learning rules, the criteria it uses to assess evidence, or its reasoning process, making effective oversight and correction impossible...only the final output is presented. The emergence of algorithmic black boxes is the result of multiple interacting factors, including technical, economic, and legal aspects. On the technical level, algorithms rely on sophisticated computer technologies, producing outputs through processes such as data collection, training, and computation using specific rules. These internal computational procedures are invisible to outsiders, making the black-box nature of algorithms almost inevitable. As technology advances, high-level algorithms can learn independently, extract data automatically, and produce outcomes without human intervention, which their developers even cannot fully understand, leading to even greater opacity. On the economic level, algorithm developers invest significant time and resources into building these systems, which can yield considerable economic benefits for themselves and their operators. As such, technical personnel often prefer to maintain or even strengthen the "black-box nature" to create technological barriers and protect their competitive advantage. Finally, from a legal standpoint, the protection of trade secrets contributes to the formation of algorithmic black boxes. As part of a company's proprietary technology, the core of legal protection for algorithms lies precisely in their non-public, black-box characteristics. This legal protection further legitimizes the existence of opaque algorithmic systems.

The existence of algorithmic black boxes runs counter to the principles of fairness and transparency. On one hand, the process by which AI examines and evaluates evidence remains opaque to human users, raising doubts about the reliability and accuracy of its conclusions. Biases or inclinations embedded within the algorithm may result in discriminatory errors that are difficult to detect or correct. On the other hand, the opacity of algorithmic operations resembles "black-box decision-making," which undermines the requirements of procedural justice. Consequently, the "black box nature" of deep learning algorithms has led many legal practitioners to question the reliability and legitimacy of such systems, making them hesitant to rely on AI tools, particularly in complex or major cases. For instance, in some grassroots courts in Jiangsu Prov-

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ince where intelligent adjudication systems have been introduced, certain judges have expressed doubts about the system's reliability and admitted they have never used it. Therefore, resolving the issue of algorithmic black boxes and achieving transparency in the structure of deep learning models is of paramount importance for the effective application of AI in criminal evidence analysis.

3.3 Risks in Judicial Applications: Conflicts Between Subjects and the Risk of Rights Infringement

Conflicts may arise between AI and judicial personnel involved in evidence review, which can lead to the erosion of judicial personnel's autonomy. In the criminal justice field, the scientific application of AI tools can assist judicial personnel with basic and routine tasks, saving time and improving efficiency. However, the rapid development of AI also poses the risk of diminishing the human agency of judicial workers. The autonomy of judicial personnel in the judicial process lies in their active participation and dominant role in legal practice. At present, many AI-assisted judicial systems already in use offer functionalities such as evidence guidance, validation, and automated generation of preliminary evidence assessments, providing standardized support for evidence review. However, as AI's capacity for evidence assessment continues to improve, there is a risk that judicial professionals will increasingly rely on it, resulting in the weakening of their own subjective initiative. Nevertheless, AI has yet to reach the level of human cognitive ability and still has weaknesses in areas such as data and algorithms. If legal professionals blindly follow machine-generated decisions without independently scrutinizing or exercising judgment, the hierarchical relationship between humans and machines may be inverted. This increases the risk of erroneous evidence evaluation and, ultimately, the occurrence of wrongful convictions. For instance, when AI uses natural language processing techniques to analyze witness statements or other forms of oral evidence, it may misinterpret meaning due to unique contexts, dialects, or linguistic styles, thereby incorporating flawed information into its evidentiary reasoning. If judicial personnel responsible for reviewing this stage of evidence place excessive trust in AI outputs and fail to proactively verify or correct these errors, the flawed output may be passed on to the next stage. Once these errors accumulate across multiple stages, they are likely to affect the final judgment outcome. Judicial immediacy is a key manifestation of the subject status of judicial personnel. It's fundamental requirements include a trial-centered approach and adherence to the principles of immediacy and orality, meaning that adjudicators must personally participate in the adjudication process, including the examination of evidence, the determination of facts, and the application of law. This demands that judges have direct access to and make independent judgments on all essential aspects of a case, rather than relying on reports or summaries from others. However, the involvement of AI in evidence analysis poses a risk of weakening the principle of judicial immediacy. If judges no longer independently examine evidence or hear arguments in court, but instead directly accept factual determinations generated by AI systems, the courtroom procedure may become a mere formality. In such cases, the judge's conviction may not be formed during the trial process, thereby undermining the principle of judicial immediacy and eroding the autonomous role of judicial personnel.

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The application of AI in criminal evidence analysis entails the risk of undermining the rights of the defense. In China's criminal procedure, the principle of equality between the prosecution and the defense is fundamental to ensuring the protection of human rights and upholding judicial fairness. However, the actual deployment of AI-based judicial assistance tools has posed certain challenges to this principle. At present, AI technologies incorporating the internet, big data, and blockchain are primarily implemented within the internal systems of public authorities such as the police, prosecution, and courts, and with increasing state investment in AI infrastructure, the functionalities of judicial big data systems are expected to become ever more advanced. However, this technological advancement appears to yield limited direct benefits for the criminal defense, and may even result in the excessive expansion of public authority, thereby impairing the rights of the defense. From the perspective of evidence collection, AI significantly enhances the investigative capacity of judicial authorities. Yet in the context of criminal proceedings, the processing of data and personal information often occurs under conditions of extreme imbalance between the data controller, i.e., the state authorities, and the data subject, i.e., the defendant, which exacerbates structural inequality within the adversarial process. Judicial organs are in a position of significant advantage relative to the accused, and this asymmetry may be further exacerbated by the application of AI technologies. Surveillance cameras, facial recognition systems, mandatory real-name registration for media users, and other tools under the big data regime enable powerful and extensive collection of information concerning targeted individuals, thereby contributing to the construction of evidentiary databases used for criminal prosecution. Moreover, given that these authorities operate with the backing of the state's coercive power, they are often able to process personal data in secret or without consent. This results in serious limitations on individuals' rights to be informed and to give meaningful consent as data subjects. From the perspective of criminal evidence analysis and application, the use of AI also poses a latent threat to the effective exercise of the defense's rights. For instance, not all personal information collected from defendants by investigative and judicial authorities through AI tools is necessarily used in formal prosecution or included in the case file. Nonetheless, such information may still enter the AI-based evidence evaluation and reasoning system, thereby influencing its analytical conclusions. In such circumstances, the defense's right to examine the case file is substantively weakened, as the disclosed materials fall short of the actual information relied upon by the prosecution. This prevents the defense from fully preparing their arguments and significantly impairs their ability to exercise the right to cross-examination. Furthermore, even if the defense were granted access to the same data sets, the lack of technical expertise in data analysis would likely hinder their ability to extract legally relevant and substantively useful information. In practice, this constitutes a substantial obstruction to the defense's legitimate exercise of procedural rights.

4 Establishing an Interactive Mechanism for the Application of AI in Criminal Evidence Analysis

When AI is applied in practice to evidence analysis, its inherent functional limitations and its potential conflicts with core values such as judicial independence and human rights protection must not be overlooked. In order to fully harness the advantages of AI while safeguarding judicial fairness and the rights of the accused, it is imperative to establish a mechanism for constructive interaction between the two. Explor-

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ing the formation of such a mechanism from three dimensions, including defining the boundaries of application, optimizing data and algorithms, and strengthening human rights protection, will help chart a rational path for the use of AI in criminal evidence analysis. This, in turn, will promote the modernization of the judiciary through technological empowerment and achieve a win-win outcome of both fairness and efficiency in justice.

4.1 Defining the Boundaries of Application: Reasonably Limiting the Scope of AI Use in Criminal Evidence

In the handling of criminal proceedings, judicial officers' scientific and efficient use of AI tools can help reduce procedural burdens, improve efficiency, and promote judicial progress. However, despite the rapid advancements in AI, it can never replace the central role of human. On the one hand, in the process of evidence examination and evaluation, AI remains incapable of fully replicating human faculties such as intuition, emotional perception, and nuanced natural language comprehension. On the other hand, judicial independence requires that decisions stem from the autonomous judgment of judicial personnel and not be replaced by machine outputs. To achieve optimal synergy between humans and machines, and to maximize the advancement of judicial reform and progress, the application of AI in criminal evidence analysis must be reasonably limited. This requires adherence to three key principles: the principle of an auxiliary role, the principle of limited applicability, and the principle of refutability.

The principle of an auxiliary role dictates that AI may only play a supporting role in the analysis and assessment of evidence. "Machines can provide suggestions and guidance to case-handling personnel, but the final decision must rest with the judge." While AI can offer legal knowledge, procedural guidance, and reference points for evidentiary assessment, it remains incapable of simulating human irrational thinking or fully absorbing the ethical norms, social experience, and moral reasoning embedded in human life. As such, AI may assist humans in making evidentiary assessments and logical inferences, but it must not replace human beings in rendering final judicial decisions.

The principle of limited applicability clarifies that the use of AI tools in judicial proceedings must be confined to specific domains. Although AI possesses powerful computational and inferential capabilities, such as assisting legal professionals in constructing evidentiary chains or identifying contradictions between pieces of evidence, its technical limitations render it inadequate in areas requiring deep human experience or value-based reasoning, such as assessing the probative value of evidence or allocating the burden of proof. These tasks necessarily rely on human wisdom. Thus, the application of AI must be clearly delineated within a defined and appropriate scope.

The principle of refutability provides the necessary prudence and flexibility in the application of AI. Given the current technical limitations of AI in areas such as quality of data and algorithmic, it remains essential to uphold the ultimate authority of legal professionals in case adjudication. As previously discussed, since the role of AI is inherently auxiliary, its outputs must be open to scrutiny and rejection by criminal justice practitioners. This principle serves as an important safeguard against the risks posed by algorithmic bias, the "black box" effect, and logical errors in machine reasoning, thereby ensuring transparency and fairness in judicial decision-making.

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In summary, AI should serve as an auxiliary tool with a limited scope of application in criminal evidence analysis. Its outputs must remain open to human scrutiny and rebuttal. Such a principled framework strikes a balance between the strengths and limitations of AI technologies, while safeguarding the independence and fairness of judicial decision-making. In this way, AI can become a powerful aid to improving judicial efficiency and accuracy without replacing the decision-making authority of legal professionals.

4.2 Optimizing the Underlying Operational Logic: Enhancing the Development of AI Algorithmic Systems

Firstly, it is necessary to provide AI applied to criminal evidence analysis with scientific, objective, and high-quality judicial data. Data is the core of algorithms, and the quality of AI judicial assistance systems often depends on the quality of the input data. To optimize AI algorithmic systems and enhance their effectiveness, it is essential to accelerate the incorporation of large volumes of high-quality data. The achievement of this goal depends on efforts in two directions: the quantity and quality of data samples. To provide AI with sufficient data for learning, efforts can begin with the online publication system of court decisions. First, court decisions should be digitized as fully as possible, including older judgments that have not yet been published. Second, the timeliness of uploading court judgments should be improved. After a case is concluded, the judge should promptly publish the judgment online to avoid excessive delays that would render the data outdated. Moreover, the approach to writing court judgments should be optimized: enhance the reasoning sections, remove content unhelpful to big data analysis, and focus on analyzing adjudicative thinking in typical cases to support AI learning. Finally, the scope of judicial data supplied for AI learning can be appropriately expanded. Besides court decisions, evidentiary data from the investigation stage and the prosecutorial stage may also be uploaded to the internal systems of the public security organs, the procuratorates, and the courts, enabling AI to conduct more holistic logical structuring and model building.

Improving the quality of sample data for AI is also a priority in optimizing AI algorithms, which relies on the input of high-quality data such as authoritative cases from the Supreme People's Court and typical cases from various levels of courts. For high-quality cases, it is first necessary to manually break down the elements and label the evidence, extracting information that aids in conviction and sentencing to provide effective materials for machine learning. This process helps AI to extract and classify evidence more accurately and efficiently, enabling it to identify logically corroborative or contradictory relationships within complex evidence. As a result, it assists judicial personnel in quickly clarifying case facts, reducing subjective errors, adhering to procedural norms, and improving judicial efficiency. Additionally, efforts should be strengthened to ensure the objectivity and authenticity of judicial data. Through expert evaluation, data screening, and other professional technical measures, the infiltration of biased data into judicial practice can be minimized; meanwhile, implementing data sharing to eliminate data silos and improve the predictability and accuracy of judicial data will also provide sufficient and reliable support for AI in criminal evidence assessment.

Secondly, the principle of judicial transparency should be integrated into the practical application of AI in evidence analysis to enhance algorithmic transparency and interpretability. The "algorithmic black box" of AI may raise concerns about judicial unfairness, and improving the transparency and interpretability of al-

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gorithms can serve as an effective response strategy. Before and after the deployment of AI-assisted judicial systems, measures such as algorithm disclosure, algorithm explanation, and the establishment of a full-process algorithm evaluation mechanism can effectively promote algorithmic transparency and interpretability. Prior to applying AI technology in the judiciary, it is necessary to conduct a comprehensive evaluation of its algorithms to anticipate their potential impact on decision-making and avoid biased outcomes. This can be implemented through algorithmic transparency measures, such as requiring developers or users to disclose algorithmic code, data sets, and decision-making logic or other relevant elements. However, the pursuit of algorithmic transparency should not be excessive; demanding full disclosure of every detail of an algorithm is neither necessary nor realistic. On the one hand, publishing massive amounts of data that the public cannot comprehend serves little purpose, and full disclosure may compromise national security, public order, or the rights of private entities. On the other hand, in cases where the algorithm operates in a self-learning mode, even its deployers may find it difficult to explain the logic behind its decisions. Therefore, limited algorithmic disclosure is a more effective approach to enhancing AI transparency: for AI platforms that provide decision-making services and involve complex algorithmic structures, it is appropriate to disclose the basic operating logic, key parameters, and potential technical risks involved in the system's functioning. Of course, mere disclosure is insufficient to achieve true algorithmic transparency, as algorithms often contain complex mathematical models and programming logic that are difficult for non-specialists to understand. Hence, algorithm developers or operators should also explain the algorithm to affected individuals using non-technical and easy-to-understand language, enabling them to grasp how and why the algorithm makes certain decisions. Algorithmic explanation helps break down the technical barrier between operators and users, improves the transparency of algorithmic decisions, and serves as an effective way to address the "black box" problem in algorithmic governance.

If the algorithmic "black box" caused by professional knowledge barriers creates an obstacle between algorithm developers or operators and the affected individuals, then the "black box" generated by self-learning algorithms constitutes a fundamental gap between humans and machines, which algorithmic disclosure and explanation can hardly bridge. In such cases, it becomes necessary to supervise the operation of the algorithm and monitor potential issues that may arise during its implementation. Specifically, once AI is applied in the judicial field, a dynamic evaluation mechanism should be established to continuously assess the algorithm's performance and outcomes. If any value bias that contradicts legal norms or ethical standards emerges, it must be promptly corrected to prevent compromising the fairness of judicial decisions. In the field of criminal justice, where fairness, justice, and the protection of human rights are of paramount importance, implementing such a mechanism is particularly essential. Some scholars argue that the primary responsibility for supervising algorithm operation lies with the algorithm deployers. These deployers can adopt mechanisms such as "compliance audits" to monitor the operation and output of algorithms, examining whether they negatively impact citizens' rights, public order and good morals, or social fairness, in order to ensure objectivity and impartiality, and to prevent adverse consequences in applications. However, there is a knowledge gap between legal professionals in the judicial field and laypersons; many technical personnel in the AI algorithm domain lack legal thinking. This makes it difficult for them to distinguish legal rules from "biases" when supervising AI assistance programs, resulting in unaddressed flaws in legal

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logic within the algorithm, which may worsen as the algorithm continues to self-learn and evolve. Therefore, only by accelerating the training of interdisciplinary legal professionals equipped with both legal expertise and digital literacy can we truly "integrate algorithms into law and law into algorithms," continuously upgrading and transforming AI systems used in the judicial field, and advancing toward a modernized judiciary empowered by technology.

4.3 Conflict Resolution and Rights Protection: Centering on the Reasonable Reinforcement of the Rights of the Accused

In the era of AI, law, ethics and technology are jointly shaping a new order. However, just as historical breakthroughs in science and technology have often deepened social inequality and injustice, the new order is frequently regarded as an "extremely unequal order." This is particularly evident in how holders of technology tend to occupy positions of greater advantage. As previously discussed, in China's criminal justice system, the introduction of AI-assisted tools has further strengthened the dominant position of public authorities, thereby posing potential threats to the rights of the accused in judicial proceedings. Therefore, to uphold the principles of equality between prosecution and defense as well as the protection of human rights, it is not only necessary to reasonably limit the use of AI within judicial authorities but also to correspondingly reinforce the rights of the accused, in order to achieve the goal of judicial fairness.

On the one hand, one major advantage of applying AI within judicial authorities lies in facilitating evidence collection, a feature particularly prominent in the investigative phase. In the era of big data, which is characterized by the digitization of individual behavior and the intelligentization of state governance, citizens' information across all aspects of life, from birth to death, is stored in various databases: travel routes are logged by ride-hailing apps; purchases are recorded by mobile payment platforms; public behavior is captured by surveillance cameras. This highly digitalized mode of social operation greatly enhances investigators' ability to use intelligent technologies for suspect tracking and case investigation, but at the same time it poses greater risks to personal information protection. To balance the dual needs of criminal prosecution and the protection of human rights, judicial authorities can draw on "the principle of notification" in personal information protection. For instance, the accused could be informed about the use of AI in judicial procedures, such as the type of AI employed, the stage at which it is used, how it functions, and the potential impact it may have, so as to ensure the defendant's effective exercise of the right to challenge evidence, without disrupting the normal progress of the case adjudication.

On the other hand, under current practices of judicial intelligentization, the lack of channels for defendants to access AI-related information significantly undermines the protection of their procedural rights. While public security organs, procuratorates, and courts establish mechanisms for sharing case-related data and gain access to vast amounts of information concerning the case and the defendant, they should also provide the defendant with channels to request access to such data. In the absence of special circumstances or reasonable grounds for refusal, such requests should be granted. If the defendant is unable to access data that is relevant to the case, influences conviction or sentencing, and yet is not included in the case file, they will be unable to formulate an effective defense strategy, which adversely affects the protection of their right to challenge evidence. Furthermore, to address the lack of transparency in evidence review and

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analysis caused by the AI "black box" problem, and to respond to the defendant's concerns regarding the decision-making process, the judicial authority may, upon request, provide a reasonable degree of algorithm disclosure. This would allow the defense to engage expert assistants in advance to assess and challenge the algorithmic program.[1]Given that ordinary citizens may be unaware of how to engage expert assistants or may not be able to afford the costs, courts could consider assigning expert assistants to defendants by analogy to legal aid lawyer provisions. This could help alleviate the imbalance between the prosecution and defense, and prevent the defendant from being unable to effectively exercise their right to challenge evidence due to technical barriers.

5 Conclusion

The application of AI in the field of criminal evidence analysis is an irreversible trend and has increasingly become a focal point in both legal scholarship and judicial practice. AI, when applied to criminal evidence analysis, presents both advantages and challenges, embodying the characteristic of a "double-edged sword." AI demonstrates great potential in improving case-handling efficiency, preventing wrongful convictions, and upholding procedural justice; however, it also presents shortcomings in areas such as the assessment of evidentiary standard, the implementation of algorithm, and the protection of judicial rights. Looking ahead, it is essential to reaffirm the auxiliary role of AI, address its weaknesses in data and algorithmic design, and reasonably enhance the legal rights of the accused. Through these measures, we can achieve an better balance between judicial fairness and efficiency, while avoiding the misuse and risks of technology, thus empowering judicial progress through the responsible use of technology.

However, the issue of liability attribution arising from the application of AI in criminal evidence analysis deserves further attention from academia. Since an operational AI system involves multiple parties, including algorithm developers, data providers, system users, and maintainers, any mistake by one party may lead to deviations in evidence analysis. The complexity of the technology makes it extremely difficult to determine the root cause of errors. Moreover, the lack of clear legal frameworks and standards to define each party's responsibility renders liability attribution unclear. When errors or deviations occur, it is challenging to accurately assess the degree of fault and the extent of responsibility each party should bear. Therefore, this issue requires further research.

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1 In Chinese criminal procedure, the legal basis for the role commonly referred to as an "expert assistant" is found in Article 192 of the Criminal Procedure Law of the People's Republic of China (2018 Amendment), which allows parties to apply for individuals with specialized knowledge to appear in court and provide opinions on expert evidence. Although the law does not use the term directly, the concept has been widely adopted in legal practice and academic discourse to refer to such party-appointed technical advisors.

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