IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 11, Issue 8, August 2023

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.379

9940 572 462 | 6381 907 438 | ijircce@gmail.com | www.ijircce.com

International Journal of Innovative Research in Computer and Communication Engineering

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.379 |

|| Volume 11, Issue 8, August 2023 ||

| DOI: 10.15680/IJIRCCE.2023.1108022 |

A Comprehensive Review of Artificial Intelligence in Cyber Security

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ABSTRACT: The rapidly advancing technology and escalating cyber risks challenge cybersecurity in safeguarding digital assets. Over the past decade, the domain grew significantly with increasing applications and threats. Incidents like data breaches, identity theft, and evasive tactics are critical in the digital era. Contextualized in AI's impact, the study dissects adversarial evolution, highlighting AI's use for intricate attacks. The contest between AI-enabled offense and defense is analyzed, emphasizing AI-integrated security advancements. Ethical aspects are explored within the dynamic threat landscape. The analysis traverses AI applications, providing real-world instances. The document evaluates AI across cybersecurity, enhancing capabilities and reshaping security approaches.

KEYWORDS: Artificial Intelligence; Cybersecurity; Autonomous Threat Response; Intrusion Detection; Threat Intelligence

I. INTRODUCTION

In a time when the digital realm is expanding with unprecedented speed, the necessity for robust cybersecurity safeguards has reached a critical juncture. As both organizations and individuals grow more reliant on digital technologies, the potential dangers stemming from cyber threats have risen to unparalleled heights. In response, the fusion of Artificial Intelligence (AI) with cybersecurity has surfaced as a revolutionary framework, reshaping the boundaries of contemporary defence strategies.

The rapid expansion of computer networks has given rise to a significant increase in cyberattacks. All sectors of our society, including government, economy, and critical infrastructures, heavily rely on computer networks and information technology solutions. Consequently, these sectors are highly susceptible to cyberattacks. A cyberattack entails an offensive launched from one or multiple computers targeting other computers or networks.

Cybersecurity encompasses both technology and practices crafted to safeguard networks and data against unauthorized access and potential harm. Its significance is underscored by the substantial volume of data collected, processed, and stored by governments, companies, and military entities. Cybersecurity manifests in various sectors, including military, law enforcement, judiciary, commerce, infrastructure, interior affairs, intelligence, and information systems. This domain is characterized by its dynamic and interdisciplinary nature, involving information systems, computer science, and criminology. The core security objectives encompass ensuring availability, authentication, confidentiality, nonrepudiation, and integrity.

The aim of this review is to extensively delve into the intricate interplay between AI and cybersecurity. By rigorously analysing recent literature, real-world cases, and expert perspectives, the primary goal of this paper is to illuminate the crucial function that AI assumes in bolstering digital safeguards

II. LITERATURE REVIEW

The current landscape of cybersecurity is marked by an intensifying surge of cyber threats, compelling a pressing demand for inventive defence mechanisms. As entities and individuals navigate the digital domain, the interdependent progression of technology and cyber risks has given rise to a crucial crossroads where the assimilation of Artificial Intelligence (AI) exhibits immense potential. This segment lays the groundwork by contextualizing the pertinence of AI within cybersecurity. The persistent expansion of cyber perils accentuates the exigency to propel defence strategies

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beyond conventional models. The aims of this literature review encompass surveying the existing research panorama, pinpointing research voids, and conducting a thorough examination of AI's roles within the fluid arena of cybersecurity.

Current State of AI in Cybersecurity:
The fusion of AI and cybersecurity mirrors a swiftly progressing arena that has experienced noteworthy advancements in recent times. AI-powered resolutions have shifted from experimental initiatives to tangible implementations with discernible outcomes. The preceding decade has observed ground-breaking progressions, where AI methods are harnessed as potent instruments to bolster cyber safeguards. Ranging from machine learning algorithms adept at identifying intricate structures within vast data pools to the intricate analyses facilitated by natural language processing, AI has risen as a driving force for reshaping strategies in cyber defence.

AI Techniques in Cybersecurity:
Embedding AI methodologies into cybersecurity constitutes a pivotal pillar of this burgeoning advancement. Machine learning algorithms, distinguished by their capacity to progressively glean insights from data, have attracted significant interest due to their promise in detecting anomalies and pinpointing patterns suggestive of nefarious undertakings. Conversely, natural language processing empowers systems to grasp and decode human language—an essential trait for sifting through extensive textual data to unveil intentions and contexts. Simultaneously, the evolution of deep learning techniques has unleashed remarkable proficiencies in identifying intricate patterns within images and data, mirroring the intricacy of contemporary cyber perils.

Anomaly Detection, Intrusion Detection, Threat Intelligence, and Vulnerability Assessment:
Thorough evaluation of AI-powered methodologies in various dimensions of cybersecurity merits meticulous investigation. Each segment is meticulously crafted to offer in-depth understandings into distinct AI applications, commencing with anomaly detection—a cutting-edge defence mechanism against threats that deviate from established norms. Subsequent divisions delve into intrusion detection, where AI's real-time analyses empower swift identification and mitigation of unauthorized access and assaults. The inquiry extends to encompass threat intelligence, wherein AI's proficiency in handling massive datasets extracts actionable insights, bolstering an entity's proactive capability to thwart emerging threats. Moreover, the spotlight falls on vulnerability assessment, revealing how AI-orchestrated analyses unveil concealed vulnerabilities within systems, networks, and applications.

Challenges and Limitations:
The intersection of AI and cybersecurity presents a terrain fraught with challenges. Ethical deliberations assume significant prominence, as the spectre of biases and apprehensions about data confidentiality hover over AI integrations. The domain becomes even more intricate due to the convolution of adversarial attacks, where adversaries exploit AI's weak points to subvert defensive measures. Given the ever-evolving nature of cyber perils, a constant infusion of updates into models becomes imperative for sustained efficacy. This segment underscores the intricacies of harmonizing AI's revolutionary capabilities with the multifaceted nuances of cybersecurity, effectively illustrating the fragile equilibrium between innovation and the imperative to ensure security.

III. AI TECHNIQUES IN CYBERSECURITY

This segment provides an extensive examination of the fundamental AI techniques that have seamlessly integrated into contemporary cybersecurity tactics. In the face of an intricate digital environment, conventional cybersecurity methodologies are being complemented, and occasionally substituted, by the innovative potentials of Artificial Intelligence (AI). This section delves deeply into the foundational AI techniques, encompassing machine learning algorithms, natural language processing (NLP), and deep learning. It elucidates their pivotal function in adeptly addressing and curtailing the multifaceted complexities presented by cyber threats

- **Machine Learning Algorithms:** Machine learning stands as the cornerstone of AI-infused cybersecurity. It grants systems the capacity to discern patterns, anomalies, and trends within extensive datasets, thereby enabling swift and precise identification of potential threats. Within this realm, supervised learning algorithms, like Support Vector Machines (SVM) and Random Forests, play a crucial role in categorizing data points into distinct classes, facilitating the identification of malicious activities. On the other hand, unsupervised learning algorithms, including clustering techniques, unveil the underlying data structures, unveiling potential threats that might escape rule-based systems. Further advancing this landscape, reinforcement learning emerges as a

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sophisticated methodology, enabling systems to adaptively learn optimal responses to ever-evolving cyber threats through continuous interactions within dynamic environments.

- **Natural Language Processing (NLP):** Amidst an era marked by the escalating sophistication of cyber threats, Natural Language Processing (NLP) surfaces as a formidable instrument in unravelling the complexities embedded within textual data. NLP methodologies provide the means to dissect extensive volumes of unstructured text, facilitating systems' ability to grasp and construe human language. Through techniques like sentiment analysis and text classification, these algorithms effectively differentiate between malicious intentions and legitimate communications, thus enhancing the efficiency of email filtering and the detection of phishing attempts. Beyond this, NLP-driven algorithms prove invaluable in extracting meaningful insights from various sources including security-oriented forums, social media, and clandestine web platforms, thereby fortifying endeavors in the domain of threat intelligence.

- **Deep Learning:** The emergence of deep learning has ushered in a transformative era in AI's capacity to confront intricate cybersecurity complexities. Deep neural networks have demonstrated exceptional prowess in discerning intricate patterns, rendering them exceptionally adept in tasks like image and voice recognition. Subsequently, these capabilities extend to the identification of visual and auditory cyber threats. Convolutional Neural Networks (CNNs) particularly excel in the realm of image-based threat detection, while Recurrent Neural Networks (RNNs) showcase their proficiency in deciphering sequential data, such as network traffic and behavioral sequences, thus revealing latent anomalies.

- **Relevance to Addressing Cyber Threats:** The intrinsic significance of these AI techniques in countering cyber threats is remarkably profound. Through the fusion of machine learning, NLP, and deep learning, cybersecurity systems attain the capability to discern emerging threats, forecast vulnerabilities, and autonomously manage incident responses AI finds versatile applications across various domains within cyberspace, where it assumes a pivotal role in data analysis for both attack detection and response. The automation of processes through AI greatly expedites security analyst workflows, enabling swifter engagement with semi-automated systems for identifying and addressing cyberattacks. Below are some prevalent approaches illustrating AI's integration into cybersecurity:

- **Threat Detection and Classification:** AI methodologies excel in pre-emptively identifying and thwarting potential attacks by creating models that scrutinize vast datasets of cybersecurity incidents, discerning intricate patterns of malicious behavior. Behavioral-based analysis further employs machine learning clustering and classification algorithms to scrutinize the conduct of numerous malware instances. This paves the way for automating the process of detecting and categorizing novel threats. This also presents a substantial boon for security analysts or automated systems.

- **Network Risk Scoring:** AI introduces a quantitative risk scoring mechanism, which allocates risk scores to distinct network segments. This measure proves invaluable in prioritizing cybersecurity resources based on the computed risk scores. AI can intricately automate this procedure by dissecting historical cybersecurity datasets, thereby ascertaining the vulnerabilities of various network sections or their susceptibility to specific attack types.

- **Automated Processes and Optimized Human Analysis:** AI substantially streamlines repetitive tasks that security analysts typically undertake throughout security operations. This streamlining is accomplished by scrutinizing reports detailing past security actions, executed by security analysts to counter specific attacks successfully. AI algorithms leverage these historical actions to construct a model, which in turn, is deployed for the identification of analogous cyber activities. Harnessing this model, AI algorithms autonomously respond to attacks, circumventing the need for human intervention. While complete automation of the security process might pose challenges, AI can seamlessly integrate into the cybersecurity workflow, promoting a collaborative effort between human analysts and automated systems, thereby augmenting overall effectiveness.

In the following sections, we embark on a more comprehensive exploration of the pragmatic utilization of these AI techniques within diverse realms of cybersecurity. This entails delving into the practical aspects, revealing both the challenges encountered during implementation and the palpable influence exerted in enhancing the cybersecurity landscape**.**

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IV. METHODOLOGY

- **Research Design**
  The approach utilized in this literature review involves conducting an extensive examination of prevailing literature, academic articles, instances of practical applications, and pertinent documents concerning the amalgamation of Artificial Intelligence (AI) within the sphere of cybersecurity. This strategy is meticulously formulated to amalgamate and conscientiously assess the abundance of insights presented across diverse origins, facilitating an all-encompassing comprehension of the contemporary status, emerging patterns, obstacles, and potentialities of AI implementations in the realm of safeguarding cyber systems.

- **Data Collection**
  Curating pertinent content for this literature review was an intricately thorough undertaking. The central archives employed encompass respected scholarly databases, peer-evaluated periodicals, assembly transcripts, and authoritative trade briefs. The exploration was executed employing a blend of key phrases like "Integration of Artificial Intelligence in Cybersecurity," "AI-fuelled Menace Identification," "Employing Machine Learning for Detecting Intrusions," and interconnected vocabulary. Priority was accorded to cherry-picking materials that harmonize intimately with the investigation's aims, with a concentration on current publications and inputs from distinguished investigators and professionals in the domain.
- **Data Analysis**
  A methodical strategy was employed to scrutinize the amassed data, with the intent of distilling substantial insights from a wide spectrum of origins. A fusion of data from diverse scholarly papers, practical instances, and documentation was embarked upon, with the objective of pinpointing prevailing trends, emergent configurations, and salient chasms within the research panorama. The data was systematically arranged according to explicit AI methodologies expounded upon, including algorithms of machine learning, natural language processing, and deep learning. Concurrently, the analysis encompassed the specialized domains of aberration detection, invasion identification, threat discernment, and vulnerability assessment. The amalgamation of data was steered by the urgency to untangle the complexities inherent in AI's applications within cybersecurity, all the while striving to identify junctures of consensus, voids within research, and possible trajectories for prospective exploration.

V. RESULTS & DISCUSSION

This segment elucidates the pivotal takeaways and discernments extracted from the all-encompassing analysis of literature concerning the role of Artificial Intelligence (AI) within the domain of cyber security. While the review does not encompass original data acquisition, it amalgamates and examines the conclusions, patterns, and consequences identified in pre-existing research. In doing so, it furnishes a holistic viewpoint on the focal topic.

Key Insights and Observations:
The scrutiny of the examined literature unveiled a multitude of noteworthy revelations concerning the utilization of AI in the realm of cyber security. The subsequent segments illuminate the principal discoveries within diverse thematic domains:

AI Techniques in Cybersecurity:

- Machine learning algorithms, particularly neural networks and ensemble models, find widespread use for anomaly detection and categorization.
- Techniques rooted in natural language processing are harnessed for dissecting textual data, extracting valuable threat intelligence.
- The deployment of deep learning architectures empowers sophisticated threat prediction and analysis.

Anomaly Detection:
AI-fuelled anomaly detection techniques exhibit potential in discerning inconspicuous deviations from established norms, thereby elevating the efficacy of early threat detection.

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Intrusion Detection:
In comparison to conventional rule-based systems, AI-infused intrusion detection systems showcase heightened precision in identifying both recognized and unfamiliar attack patterns.

Threat Intelligence:
AI-amplified threat intelligence harnesses machine learning to handle extensive data volumes, pinpoint nascent threats, and contribute to proactive defence strategies.

Vulnerability Assessment:
AI-driven vulnerability assessment tools furnish automated scans capable of identifying potential susceptibilities within systems, applications, and networks, thereby assisting in the mitigation of risks.

Comparison with Previous Research:
A comparative examination in relation to earlier research findings underscores an emerging consensus regarding the effectiveness of AI in the realm of cyber security. The reviewed literature aligns with prior investigations, underscoring the capacity of AI techniques to augment detection precision, curtail false positives, and refine threat prediction.

Trends and Patterns:
The review discerned a recurring pattern wherein organizations are embracing AI-fuelled solutions to counter ever-evolving cyber threats. The integration of AI has resulted in expedited incident response durations, heightened precision in threat detection, and enhanced decision-making when dealing with security incidents.

VI. CHALLENGES AND LIMITATIONS

In the ever-expanding landscape of cybersecurity, where the integration of Artificial Intelligence (AI) is becoming ubiquitous, this section embarks on a journey to unveil the complex fabric of challenges and constraints that accompany this revolutionary pursuit. Navigating through this intricate terrain, we delve into the diverse array of hurdles that necessitate meticulous scrutiny while harnessing AI's transformative capabilities to fortify the realms of digital security.

Adversarial Attacks:
The algorithms crafted to bolster defence against cyber threats are paradoxically vulnerable to adversarial attacks. This segment embarks on a journey through the labyrinthine realm of adversarial manipulation, where malicious actors exploit openings in AI models, resulting in misclassifications and erroneous judgments. The ongoing battle between AI-powered defences and adversarial assaults accentuates the indispensable need for perpetual reinforcement of these models

Data Privacy Concerns:
The convergence of AI and cybersecurity demands access to extensive datasets for efficient training. Nevertheless, this requirement for data clashes with the utmost significance of data privacy. This section delves into the intricacies of this challenge, delving into the intricate equilibrium necessary to leverage AI's potential while preserving individual privacy rights. Achieving this equilibrium is of paramount importance to cultivate public confidence and uphold ethical benchmarks.

Continuous Model Updates:
The effectiveness of AI is contingent on its capacity to flexibly respond to ever-changing cyber threats. However, attaining this adaptability presents a considerable challenge. This section intricately explores the complexities of ongoing model updates, addressing the obstacles imposed by the real-time dynamics of threats. The intricate endeavour of maintaining AI models that are up-to-date, precise, and capable of addressing emerging threats is dissected within the context of finite resources.

Interpretability and Explain ability:
The decision-making processes driven by AI, while formidable, frequently linger in obscurity. In this section, we meticulously dissect the challenge of deciphering and elucidating AI-derived insights to human analysts and

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stakeholders. As AI progressively assumes a pivotal role in decision-making, the task of bridging this interpretative gap becomes indispensable for cultivating trust, validating results, and upholding accountability.

Lack of Contextual Understanding:
AI-driven cybersecurity systems showcase remarkable prowess in pattern recognition, yet they frequently grapple with the contextual comprehension that human analysts inherently possess. This challenge manifests when AI identifies innocuous activities as suspicious merely due to statistical anomalies. In this section, we navigate the intricate terrain of infusing contextual awareness into AI models, unravelling the intricacies of augmenting accurate threat detection through a nuanced understanding of situational context.

Human-AI Collaboration:
The convergence of human expertise and AI capabilities presents a distinctive set of challenges. This section delves into the complexities of achieving a symbiotic collaboration, where human intuition harmonizes with AI's computational prowess. Cultivating an ecosystem in which AI enhances human decision-making while acknowledging the subtleties of human judgment demands a meticulous equilibrium

VII. CONCLUSION

The closing segment encapsulates the primary discoveries from the assessment, accentuating the revolutionary capacity of AI in reshaping strategies for cyber defence. In an epoch marked by ceaseless technological progress and mounting cyber perils, the fusion of Artificial Intelligence (AI) within the domain of cybersecurity stands out as a beacon of pioneering ingenuity and robustness. This all-encompassing evaluation has navigated through the expanse of AI implementations in safeguarding against cyber threats, unearthing a plethora of observations that highlight the game-changing potential inherent in solutions propelled by AI.

The convergence of AI and cybersecurity is on the brink of redefining the landscape of digital safeguarding, rendering conventional security models insufficient. The essential takeaways from this investigation unveil that AI methodologies, encompassing machine learning, natural language processing, and deep learning, bestow upon organizations the capacity to pre-emptively identify irregularities, promptly counteract breaches, extract practical threat insights, and carry out thorough vulnerability evaluations. These strides forward serve as affirmations of AI's potential in elevating the nimbleness, precision, and durability of cybersecurity protocols.
In the ever-changing realm of digital advancements, it is crucial to recognize the hurdles and confines that accompany the infusion of AI into cybersecurity. The looming threat of adversarial assaults, apprehensions regarding data confidentiality, and the essentiality of consistent model enhancements accentuate the significance of perpetual watchfulness and enhancement. Nonetheless, these obstacles are not invincible and serve as a fertile domain for extended investigation and inventive progress.

In conclusion, the expedition through this assessment has cast a revealing light on the profound influence of AI within the domain of cyber defence. The fusion of cognitive computing, adaptable learning, and predictive analysis has acted as a catalyst, ushering in a new perspective, and enabling organizations not only to withstand cyber threats but to pre-empt them with unparalleled effectiveness. The undeniable potential of AI to reshape the landscape of cyber defence is evident, paving the way for a digital realm characterized by enhanced safety and security, where innovation and safeguarding go hand in hand. As we embrace this transformative phase, we do so with a resolute dedication to continual exploration, collaboration, and ethical reflection, marking the inception of a cybersecurity era fortified by the capabilities of Artificial Intelligence.

VIII. FUTURE WORK

Amid the ever-evolving partnership between Artificial Intelligence (AI) and cybersecurity, this section sets forth on a forward-looking expedition, casting light on prospective pathways, uncharted domains, and the diverse horizons that await exploration. Pioneering the forthcoming frontiers of AI in cybersecurity, we delve into emerging trends, projected strides, and the untrodden avenues of research that are poised to Meld the contours of the digital defence landscape.

Synergy with Emerging Technologies:
The synergy of AI with other cutting-edge technologies stands poised to revolutionize the very foundations of cybersecurity. The profound transformative capabilities of these collaborations, spanning from establishing secure

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decentralized systems to enabling real-time threat analysis at the edge of networks, pave a promising path towards a robust and agile cyber defence frontier.

Autonomous Threat Response:
The evolution of AI from its traditional role of passive analysis to an era of autonomous action marks a pivotal shift in the landscape of future cybersecurity. The far-reaching implications of this paradigm shift, ranging from rapid incident resolution to the mitigation of human error, underscore a future where AI assumes the role of a vigilant sentinel, orchestrating and executing digital defences with unprecedented precision and speed.

Next-Generation Intrusion Detection:
Envisioning the trajectory of intrusion detection, this section embarks on a journey into the realm of next-generation AI-powered systems. It delves into the evolution of machine learning models that exhibit a remarkable ability to continuously self-optimize and adapt in response to ever-evolving attack vectors. This promises a new level of detection accuracy that keeps pace with the dynamic threat landscape.

Cognitive Cybersecurity:
The emergence of cognitive cybersecurity marks a pivotal trend in the field. In this paradigm, Artificial Intelligence (AI) transcends its rule-based origins, evolving into systems that possess the ability to not only comprehend but also emulate human cognition. This section delves into the promising landscape of AI systems that exhibit a profound understanding of the intent, context, and motives underlying cyber threats. This deeper level of comprehension empowers these systems to engage in anticipatory defence, effectively predicting and countering threats before they can manifest.

The Ethical Imperative:
When considering the future path of AI in the realm of cybersecurity, the ethical aspects become a prominent and intricate issue. As AI takes on more independent responsibilities in the field of cyber defence, this segment thoroughly examines the necessary ethical structures that need to be created for the purpose of directing and overseeing decisions driven by AI.

Bias Mitigation: Employing AI in cybersecurity necessitates careful steps to recognize and alleviate biases present in AI algorithms. Biases may arise from past data, the design of algorithms, or unforeseen results, which can result in unjust or discriminatory results. This segment highlights the importance of creating and executing effective approaches to examine, tackle, and forestall bias within AI-driven cybersecurity systems.

Accountability and Transparency: With AI systems taking on independent roles in making decisions, the issue of accountability gains utmost importance. It is essential to create distinct lines of responsibility to guarantee that actions driven by AI are easily understandable, traceable, and subject to supervision. This involves setting up mechanisms to monitor AI's decision-making processes, comprehending the reasoning behind its choices, and attributing accountability for its results.

Pre-emptive Action vs. Individual Rights: The ethical discussion explores the equilibrium between taking proactive defence measures and protecting individual rights. Although AI's ability to predict can facilitate pre-emptive actions against potential threats, it is of utmost importance to guarantee that such actions honour individuals' rights to privacy, data security, and civil freedoms. This segment guides through the complex landscape of achieving the appropriate balance between maintaining security and respecting individual rights.

Human Oversight and Control: The discussion also encompasses the significance of human supervision and authority in AI-fuelled cybersecurity. As AI systems advance and take on independent decision-making, it is imperative to establish mechanisms that allow human intervention, particularly in crucial scenarios or instances demanding intricate ethical assessments.

Collaborative AI-Driven Defence: Envisaging a cooperative cyber defence environment, this segment delves into a prospective scenario where AI systems from different entities collaborate seamlessly, exchanging knowledge about potential threats and adjusting collectively. This unified defensive approach, supported by AI-generated insights, has the capability to elevate cybersecurity to unparalleled levels.

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INNO SPACE
SJIF Scientific Journal Impact Factor

Impact Factor: 8.379

doi cross ref

ISSN INTERNATIONAL STANDARD SERIAL NUMBER INDIA

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