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Enhancing Cybersecurity Through AI-Driven Predictive Threat Intelligence Systems

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Abstract

The integration of Artificial Intelligence (AI) into Predictive Threat Intelligence systems on a cybersecurity basis is examined. The focus is on AI-driven Predictive Threat Intelligence systems' potentialities in strengthening protective capabilities against cyber threats on a cybersecurity scheme, particularly with respect to the next-generation Alpha defense scenarios. The current cybersecurity schemes as well as emerging threats and tactical defense methods are discussed. Intelligent approaches including Machine Learning (ML) and Deep Learning (DL) algorithms are introduced, implemented, and tested in order to identify and mitigate the rapid-fire, evasive, and bursting-piece cyber threats which are predicted to be emerging with severe consequences such as strategic cyber/physical sabotages, data breaches, and permanent damage. Additionally to conventional investment into cyber firewalls and protection gaps, most of the private enterprises and nation-states have been engaging in predictive readiness, and even preemption of the forthcoming cyber threats by the integration of Predictive Threat Intelligence (PTI) Systems. The PTI systems collect, process and analyze massive-scale cyber incident data and emerging hazard signals, and further utilize that data for predicting possible threats, vulnerabilities, and impacts. In such monitor-detect-predict-defend cybersecurity mechanisms of the upcoming Beta defense scenarios, the implemented PTI systems turn out to be standalone defensive units. The upgrade of PTI systems with AI capabilities such as data analytics, ML, and DL that automate early recognition, granular event analysis in semi-real time and speed-up commitment of the remediation measures.

Keywords: AI, cybersecurity, predictive threat intelligence, cyber threats,AI-based cybersecurity,Predictive threat intelligence,Machine learning security,Cyber Attack prediction,AI threat detection,Proactive security solutions,Cybersecurity automation,Threat intelligence systems,Predictive analytics in cybersecurity,AI-powered defense mechanisms.

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1. Introduction

Cybersecurity is increasingly vital in the contemporary technological landscape. With data breaches being a daily occurrence, conventional security measures are no longer sufficient to protect sensitive information. Modern cybersecurity breaches present data losses, service disruption, or even significant financial losses. It is because the volume and sophistication of cyber threats continue to multiply and grow. The cyber threat activities are also constantly evolving, becoming more difficult for conventional security measures to recognize, block, and forecast. So, network security, which is today's chief concern, has an ongoing task to renovate itself to deal with severe cyberattacks in a variety of fields.

Recently, Artificial Intelligence (AI) technologies have gained increasing attention and demonstrated prodigious capabilities in numerous tasks. AI innovations are used across the cybersecurity landscape to tackle cyber threats, by identifying, preventing, and responding to threats in cyberspace. Organizations and national governments invest heavily in AI capabilities to strengthen their defenses and safeguard their sensitive data. This essay will introduce the basic role of AI technologies in cybersecurity, particularly predictive threat intelligence as the foremost transformation which is entering the spotlight in current years. A deeper discussion of the concept and capabilities of predictive threat intelligence will be complemented by its broader implications and the endeavors made to develop such systems in academia and private industries.

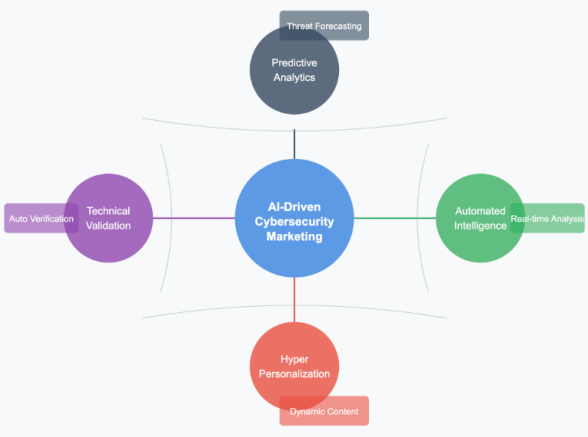

Fig 1: Cybersecurity Marketing AI-Driven

1.1. Background and Rationale

The Cybersecurity field has been significantly transformed during the last sixty years. Initially, security was just a physical term and limited to tangible beings. Later, security has expanded to other spaces such as organizations and information. With the digitalization of the world, a vast amount of data has been accumulated in cyber-physical systems and artificial intelligence. However, the accumulation of information places the shared resources at risk where attackers can exploit them. This study reviews the background on how security approaches related to different aspects of locations have been evolved. Also, the evolving trends and research outlook are identified to guide further research directions.

Cybersecurity has been an essential field to be concerned with the rise of computers in the early 1980s. Since then, cybersecurity techniques and hacking techniques have evolved simultaneously. Malicious cyber-attackers keep questioning the security of digitized information systems. Various companies and governments try to protect their systems from this cyber-threat. However, in this endless cycle, it seems that the harmful side has been one step ahead. Most cybersecurity protection models have a defensive approach, which is not an efficient way to combat attackers. The ultimate aim is to build an AI security system that is successful in applying offensive security. Deployment of cognitive; specifically predictable AI, based policy action before an attack will be revolutionary than today's security systems.

Digitalization improves the quality of life, yet it brings new security concerns due to vulnerable interactions. In recent years, many crucial cyber-attacks caused the loss of significant value. State-of-the-art protection is achieved by reactive systems, and a breach should be done to study the attack method and actor rendered late recovery. Many systems like Intelligent Intrusion Detection Systems have been improved for early attack discovery. These systems analyze the traffic of the acting party during the attack together with historic intelligence and learn a suitable alarm model. Even so, pro attacks with new harmful methods are very difficult to detect. The pattern of the first strike, which defines the tactics and overall attack plan, is not well understood by any authority.

Equ 1: AI-based Anomaly Detection (AAD) Algorithm

$$AAD = \frac{1}{n}\sum_{i=1}^{n}\left(|x_i - \hat{x}_i|\right)$$

Where:

- x_i is the observed data point (e.g., traffic behavior)
- $\hat{x}_i$ is the predicted data point (e.g., expected normal behavior)
- n is the number of observations

1.2. Research Objectives In light of the exponential volume increase of cyber-attacks each day, authorities realize the seriousness of the situation and the lack of employee awareness, high usage of the internet, and lack of security measures adds more reasons to that. Many businesses believe they are immune to cyber-attacks due to a low profile among cyber attackers. This however is not the case in reality as an empirical investigation will be conducted to resolve this hypothesis. A statistical study was conducted amongst financial institutions in order to better understand their experience with cyber-attacks. AI-driven predictive threat systems can detect cyber-attacks that traditional security methods fail to. The key research addresses artificial intelligence's capabilities in enhancing predictive threat intelligence systems.

To add further credibility to the research findings, an example hacker scenario is simulated to predict how businesses are vulnerable to cyber risks and attacks. This scenario empowers authorities and organizations to understand risks and threats. They can also develop and train their employees to be prepared for future cyber threats. An example hacker simulation will be conducted that considers both external and internal factors, yet ignores malware and physical damage. The objective is to illustrate how organizations' employees' information could be

stolen, altered and deleted by external cyber attackers. The simulation is accomplished through a remote simulation that targets a generic fictional auditing financial institution. This is an illustrative example of how a real-world problem affects companies that have a widespread online presence, but insufficient cybersecurity measures. In the realistic example shown, the company is a financial institution, thus an intangible sector interest to cyber attackers due to its vast amount of digital information.

The research highlights AI-driven predictive threat intelligence systems' capabilities to improve the efficacy of threat detection and security incident response. The prospective research is proposed, including the development and investigation of impact-oriented AI-driven solutions for enhancing predictive threat intelligence, and their evaluation in real-world scenarios. Technical and ethical challenges that are commonly found in the development, deployment and operation of AI-driven predictive threat intelligence systems are also covered, reflecting on how such systems can be made equitable, secure, democratic, efficient, transparent, robust and beneficial for the public.

2. AI in Cybersecurity

This past decade has seen an explosion in AI possibilities, generating huge impacts across sectors and individual lives. Hundreds of AI applications subtly in use or impossible a few years back are now considered vital, and their absence represents barriers rather than benefits. Even complex tasks devoid of repetitive heavy manual components can be (and are) automated. One such case presents cybersecurity and information security, baked over decades into software or appliances. Until recently, this also produced plenty of work and maintenance requirements at a hefty price. Sprawling digital existence now far outpaces manual protection capabilities, requiring smarter, quicker, and more efficient protection systems, a gap AI easily fills.

True, AI is no longer just a trend or a nice impracticality. The adaptability of network protection paradigms enabled protection based on learning from vast datastreams no person could reliably analyze. The result is a dynamic, self-updating, adapting protection system, often based on machine or deep learning. It effectively eradicates slate whitelisting rules and semi-static policies. New solutions based on up-and-coming natural language processing are also gathering traction to streamline and enhance policies, alerts, or reports, akin to a vacation email backlog. Meanwhile, predictively addressing threats before their launch is the fastest detection and blocking approach, predicting the adversary, not their defense. Furthermore, the weaknesses found in this niche are mostly related to the oversell of AI prowess. AI protection systems are only as good as the data used, and with manually-operated entries, the prognosis is bleak. Another pervasive problem arises from the potential biases in the analyzed data. Some common AI solutions are vulnerable factory-backdoored formats or issues with discovering zero-day threats from non-private sources.

Fig 2: AI in Cybersecurity

2.1. Applications of AI in Cybersecurity With cyber attackers becoming increasingly sophisticated, AI-driven predictive threat intelligence systems have emerged as the most promising approach to enhance cybersecurity. AI in cybersecurity applications is expected to become the new order for not just protecting critical information, but also to harden the effectiveness of physical security systems. In practice, this could range from predicting the next avenue of attack to proactively hardening the attack surface. The increased sophistication of cyber attackers is forcing organizations to rethink their cybersecurity strategies and bolster their defenses. Cyber-attacks are one of the top three most likely and most impactful risks facing the world today. These attacks are no longer being carried out by amateurs, but by sophisticated groups using advanced techniques and tools. Systems using AI are increasingly being brought to bear in the fight against these foes. Adversarial attacks are on the rise in the security space and AI in cybersecurity is no exception. Hackers are attempting to generate novel attacks on the machine learning algorithms used in cybersecurity applications. To protect themselves, security tools are now using ML and AI systems of their own to detect and respond to these sophisticated threats. AI security systems are increasingly being used to benefit the defensive side of the cyber security domain. They augment the capabilities of security teams, allowing them to focus on complex incidents rather than having to monitor vast amounts of data coming in every day. In doing so, AI security systems allow for a quicker response time and earlier detection of breaches. More sophisticated security teams have already integrated machine learning models and Behavioral AI. In one application, an AI Security Operation Center solution is already monitoring an entire network for the Intrusion Detection System. This setup uses passive intelligence to search for Indicators of Compromise, generating deep learning models.

3. Predictive Threat Intelligence Systems

Cyber threats today are evolving faster than organizations can keep up with. At the same time, the attack surface is becoming more complicated as infrastructures modernize and incorporate technologies such as edge computing, mobile, cloud and 5G. Protecting these modern and distributed infrastructures requires ever more comprehensive and scalable cybersecurity strategies and solutions. Traditional insular and perimeter-based defensive strategies have proved ineffective in addressing such threats, prompting a transition to more intelligence-based cybersecurity models. It is in this context that the field of cyber threat intelligence was born, offering an opportunity to radically overhaul cybersecurity responses. Cyber threat intelligence involves the collection and analysis of data used to understand evolving cyber threats. Ultimately, the objectives are to anticipate and prevent the threats from manifesting. At the

core of predictive threat intelligence systems lie data analytic techniques and machine learning algorithms that are used to correlate and understand data or events viewed in the context of threat intelligence information. Such systems use different types of data sources, which are combined with detailed analytics to provide timely and actionable intelligence. As cyber threats can come in many different forms and from many different sources, increasingly these systems are looking for evidence of potentially successful threats, rather than those simply already observed. Considering cybersecurity measures are traditionally reactive, this refocus represents a turning point in proactively preventing attacks, rather than only reacting to them once they have occurred. It is anticipated that utilization of these systems will become more prevalent in modern cybersecurity strategies and solutions, making these core in efforts to protect critical infrastructure.

For instance, if it is known an adversary will target a specific IT system, immediately intelligence suggestions will be observed network traffic looking for scans targeted toward the identified system before an intrusion starts. The adversary's initial exploitation attempt will also be considered an indicator of this attack style. In consequence, the system's defenders will be able to act promptly in blocking incoming malicious traffic toward the targeted system. More generally, cyber defenders will have the opportunity to preempt adversarial actions by anticipating their future steps, a fundamental concept in strategic scenarios. The establishment of this kind of proactive security posture is strongly supported by the provision of timely and accurate intelligence to security decision making. In the short term, such intelligence should be actionable, conferring the possibility to undertake the necessary measures to avert the detected threats - both by means of automated mechanisms and human intervention. In addition to timely actionability, the intelligence must contain sufficient detail. This attribute is crucial in understanding the nature of the threats and better implementing proper responses. However, low-level detailed intelligence cannot always be provided and decreased detail reporting is more common. A second aspect of preventive intelligence is its disposition of requesting an action or a chain of actions. This type of intelligence is also actionable, but not as concise as alerting, requiring the performance of a set of steps. Info-sharing is paramount in this scenario. Cyber threats have been exponentially growing in terms of number and variety over the years. Fostering collaboration among different entities in the cyber ecosystem is desirable in order to contrast effectively malicious intents. An important role in orchestrating these interactions is carried out by Computer Emergency Response Teams (CERTs) and similar public and private organizations. A recent trend in this direction is the adoption of Big Data-oriented SIEM platforms offering capabilities for processing and managing attack data and logs coming from different sensors and monitoring systems. At the same time, CERTs are developing information sharing mechanisms via secure platforms or forums, albeit larger efforts should be carried out with regards to fine-tuning this information in order to make it more useful for the stakeholders. Rapidly growing security measures are being adopted by organizations in order to better protect their valuable assets. Nonetheless, cyber criminals have been increasing their efforts in order to bypass these security measures by developing more sophisticated attack strategies. Moreover, the commercialization of gigabit networks and the increasing number of components in modern IT infrastructures are additional significant factors that could facilitate and hide adversarial activities once the intrusion has taken place.

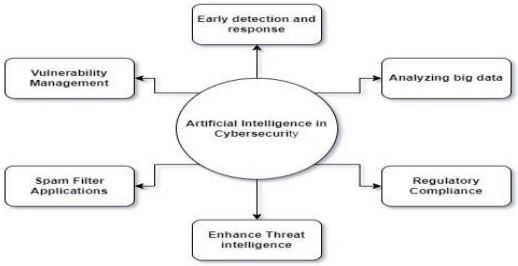

Fig 3: AI-Driven Predictive Analysis Cyber Threat Intelligence

3.1. Definition and Components The rapid increase in cyber-activity has fundamentally altered traditional approaches to cybersecurity, rendering proactive and intelligence-driven strategies progressively more important. To mitigate such threats, predictive threat intelligence systems have emerged as instrumental components of a cyber defense architecture . Broadly defined, these systems maintain a continuous data lifecycle that involves the collection and analysis of threat-related data to generate actionable intelligence for potential threats or attacks against a target. The analysis results are later disseminated to the affected component as threats are identified. In practice, this concept involves a variety of networked components that function in synergy. This section will elucidate the core components and proposed frameworks that give life to predictive systems and explain how, through a cyclic process of data collection, analysis, and dissemination, they facilitate the timely identification and remediation of potential cybersecurity incidents. This includes the methodologies, analytics platforms, and reporting mechanisms commonly used in the analysis of threat data, as well as the prerequisites and challenges surrounding its implementation. Further, this section will describe the typical organizational roles responsible for the operation, analysis, and dissemination of threat actionable. Awareness of these components is necessary to appreciate the complexity in deploying a predictive intelligence capability, while also deconstructing common misconceptions often held by analysts new to the field. Moreover, this section aims to dispel some common myths about threat intelligence, particularly with regard to the distinction between reactive and predictive approaches. Inherently, though, there is an appreciation that the straightforward definition belies the immense practical challenges in developing a flexible and scalable system that can evolve with an adversary.

The above components are used in tandem with a large 3rd-party malware analysis provider. Situational awareness is maintained by monitoring all community reports, obtaining key results for additional follow-up analysis. The results of internal analysis are disseminated to partner orgs. Much focus is given to the activity of threat actor groups with a known propensity for targeting industrial control systems.

With a greater sense of cyber-awareness, industrial control systems (ICS) have increasingly become high-value targets of cyber-espionage sets and resourced advanced campaigns, such as those sponsored by nation-states. Capabilities and TTPs are being consistently honed by such threat actors. The centralized functionality of the ICS landscape makes it especially vulnerable to malicious actors if even a single component in the network chain is compromised. From the perspective of a lesser-stocked adversary, foreknowledge of immunities, future intents, and potential success in-site reconnaissance detection alerts and, rather than abort, shift tactics

away from well-scoped targets. Indices of TTPs feed back into the system for analysis and eventual alert generation in a cyclic fashion. It is during this feedback and adjustment stage that further researcher attention will be paid.

Equ 2: AI-Driven Risk Assessment (R)

$$R = \sum_{i=1}^{m} (p_i \times s_i)$$

Where:

- p_i is the probability of threat occurrence
- s_i is the severity of the threat if it occurs
- m is the number of potential threats evaluated

3.2. Benefits and Limitations

Advanced AI-driven solutions able to predict cyber threats are considered as the last bastion in the fight against an increasingly sophisticated cyber criminality. An approach based on predictive threat intelligence is introduced that builds on advanced security analytics and machine learning solutions. The proposed cyber defense framework combines statistical, behavioral and data-mining techniques to reveal invisible and concealed malicious patterns and relationships in emerging threats. The complex attack anticipatory capability is wide, including the prediction of new zero-day attacks, the forecasting of any data exfiltration even before this is planned, and the identification of shadow security gaps, being all these kinds of threat conditions undetectable by classical state-of-the-art security mechanisms. The discussion is actually a bit of a more complicated issue than just a new ‘detection’ opportunity. First, advanced machine-learning techniques are sparked by data. In effect, predictive threat intelligence in the cybersecurity sector can be sharpened down to ‘machine-learning/AI technologies spark new cybersecurity insight basis patterns in the data’ – the product of data being obtained, cleaned, harmonized, and labeled in keeping with the rationale and methodologies applied of the machine learning (ML) model. One main advantage of ML in cybersecurity is the ability to generate results that could not be easily foreseen by cybersecurity professionals in regard to newly compiled and labeled repositories. On top of the aforementioned, advanced algorithms are primed to extract maximal pattern discovery out of data. Yet the ability to filter out ‘good’ features from the feature set in early detection, prediction, classification, etc., to outmaneuver the adversary, makes ML approaches sophisticated, in defiance of traditional rules-based systems. When operated effectively, systems of this kind could render a whole swathe of attacks previously cloaked by their craftsmanship straightforwardly detectable, as correlated and hidden relations on which the attack is grounded can be exploited to the defender.

4. Integration of AI and Predictive Threat Intelligence

Rapid advancements in the integration of AI technologies within predictive threat intelligence systems have shifted focus towards the synergy between these two domains. This is particularly relevant when considering the recent massive datasets of threat intelligence that have demanded innovative analytics methodologies for their processing. Here, predictive analytics based on AI has enriched the landscape of threat intelligence, greatly enhancing the spectrum

of actionable information. Empowered by AI algorithms, predictive threat intelligence can drill deeper into security data, providing a more accurate means of identifying and forecasting vulnerabilities and threats. This exploration discusses the above concepts, introducing the principles of AI-driven predictive threat intelligence systems based on case studies and top methodologies through illustrative figures on how AI is used to automate the entire process. Further, the most transformative nature of machine learning algorithms, as regards identifying emerging threats and adapting to changing hacking strategies, are covered. Finally, to keep AI systems on track, it is crucial to maintain a sound feedback loop with human analysts, whose abilities remain irreplaceable in the detection and analysis of intelligence.

The integration of AI with threat intelligence analytics necessitates a supportive infrastructure able to efficiently store and process large volumes of security data, and adjustments at the organizational level are equally required, namely data sharing agreements among member organizations, adoption of a common standard by information security vendors, a maturation of security vendors' capabilities in data inspection, standard definition of threat intelligence categories, and lastly, adoption, on a larger scale, of the already-existing infection feedback loops between the cybersecurity technologies of companies and security information providers. At this juncture, a predictive threat intelligence platform aids in the detection of cyber security risks by automating in-depth analysis based on massive data. With the capacity to handle a large amount of real time data combined with strong analytics for automated alerts, there will be an increase in the strategic importance of threat intelligence, which will further help autonomous threat response to develop a more robust, proactive security disposition.

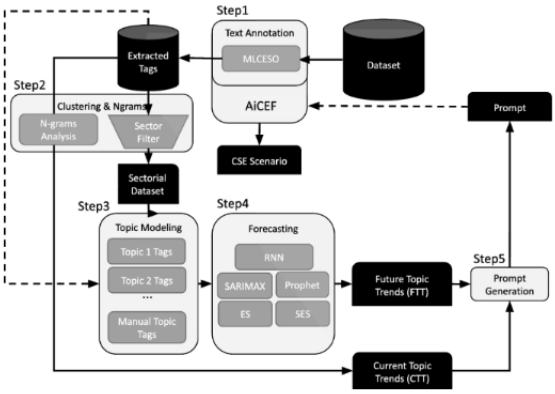

Fig 4: Integrating AI-driven threat intelligence in the cyber security

4.1. Use Cases and Examples The most transformative power of AI and machine learning in IT security procedures in recent years is arguably in the integration of AI in predictive threat intelligence systems. These use AI technologies to tackle threat data and generate predictive insights, leading to near real-time threat detection and prompt incident response. Trends in the integration of AI in current cybersecurity architectures are discussed to improve predictive threat intelligence processes. In addition, the most successful attempts to this integration are illustrated through a diversity of use cases and real-world examples, and the lessons learned from these implementations - including trade secrets, best practices, and potential pitfalls to avoid - are discussed.

A diverse array of use cases related to the successful integration of AI into predictive threat intelligence systems can be found. There are real-world examples also illustrating how AI technologies can be harnessed effectively to enhance cybersecurity. Use cases in finance are included, where the application of AI technologies has notably improved the threat data analysis, the promptness of the incident response, and as a result, the overall security management. The AI-powered network monitoring solution is one such case. The gradual learning solution of this system readily adapts to the dynamically changing network environment and can detect even the subtlest signs of the threat, even before the compromise takes place. Initially focused on the financial sector, this solution has since expanded to other industries, such as healthcare and manufacturing, to provide all-inclusive enterprise security management.

5. Challenges and Future Directions

The potential of AI-driven solution providers and upcoming trends are undeniable. Cybersecurity has become a significant commodity. The practice of cybersecurity has improved dramatically in recent years, affording a far deeper understanding of the measures needed to keep systems and data secure. AI-based solutions have grown and expanded to provide suitable and tailored algorithms capable of enhancing security measures. Although AI-driven solutions can improve security posture significantly and help in decision-making, most existing solutions remain unable to interfere, direct, or take action against the vast number of security attacks and incidents. The increasing attack vector has become complex and polymorphic across recent services and applications over the Internet. Consequently, an effective detection and defense mechanism is required to uphold system security. However, complex and sophisticated issues remain, including the development of elaborate and effective security models representing digital systems and networks, the need for considerable expertise, capabilities, and cognitive skills to deeply understand the vast variety of existing security incidents, and a common understanding is essential to effectively deploy AI-based security solutions. There are still challenges to be addressed to unlock the potential of these solutions and to prepare the ground for the next generation of AI-based security solutions robustly.

A proactive approach to threat intelligence has become an invaluable tool in the ongoing battle between attackers and defenders. Organizations have started to leverage artificial intelligence algorithms, including NLP, to reduce the time between data collection and threat mitigation. Yet there are some ethical considerations regarding who or what defines good and bad cyber behavior and how they use captured data. On the other hand, in the age of online information sharing, there has been very little attention to individual’s privacy and how threat intelligence data might be used in malicious ways. Although AI-based solutions can assist in recognizing previously unknown malware actions and behavior, such solutions can be directed and possibly biased deliberately. The accidental encoding of biases might also bring unintended consequences.

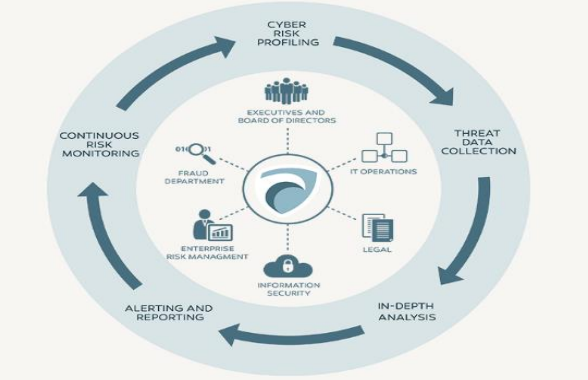

Fig 5: Challenges of Enhancing Cybersecurity

5.1. Ethical and Legal Implications The integration of artificial intelligence (AI) in predictive threat intelligence systems raises significant ethical and legal implications. Extending the application of AI into cybersecurity stimulates new concerns about data privacy, surveillance, and transparency. Developments in AI technologies urge an ongoing awareness of how to approach the ethics of innovation. The performance impact and ethical considerations of integrating AI in predictive threat intelligence systems intend to guide the development of responsible AI technology. Practices for the cybersecurity industry's ethical deployment of AI are provided. The ascent of AI can exacerbate existing threats to data privacy by systemizing and scaling surveillance practices. The question of how AI-generated threats will be handled amongst and within nation-states is a meeting point for several domains. As companies increasingly grapple with the disparate impacts of AI deployments on users and societies, the industry must develop tools to help assess those risks. These tools should be embedded into systems and software development life cycles from inception through implementation. Cross-disciplinary discussions are urgently needed to refine understandings of what an adequate risk assessment process consists of and develop appropriate methodologies for assessing AI applications. Furthermore, transparency and explainability have emerged as critical properties for AI systems for both technical and ethical reasons. AI system development practices that may pose unreasonable harm to users or data subjects must be overhauled. The problem of enforcing compliance with good practices is complex and requires changes not just on the part of developers, but possibly within the structure and incentives of the wider industry. There are no regulations that dictate how AI systems must be designed, and in the current environment, there is not even consensus on what such regulations might look like. It is unclear to industry what the legal obligations may be, but it is critical not to wait for legal precedent before contemplating these potential issues. By the time a law is passed it is likely to be too late to design and implement compliant systems. Further, should industry design harmful AI systems; the user who is hurt may or may not have the ability to perceive the harm or may not be the party subject to the worst effects. Thus, it is necessary to engage practitioners, legal experts, and policymakers in order to develop tools and solutions that can be utilized by cybersecurity professionals.

Equ 3: Adaptive AI Defense Model (ADM)

$$ADM = \sum_{i=1}^{n} (\alpha_i \times p_i \times d_i)$$

Where:

- α_i is the adaptive weight for defense strategy i
- p_i is the priority level of defense strategy i
- d_i is the defense effectiveness of strategy i
- n is the number of defense strategies

6. Conclusion

State of the Art of Advances in AI-driven Threat Intelligence Systems to Address the Future Directions on Cyber-Defence

Human dependence on digital infrastructures during the last decades has grown exponentially. This profound dependency brings an array of security challenges in cyberspace, manifesting in an ever-increasing frequency of disruptive cyber-attacks on both business and critical infrastructures. Thus, an urgent need has risen to strengthen security capabilities to fend off unauthorized accesses and safe-keep sensitive information. To this end, an increasing number of private enterprises and nation-states are searching for innovative, effective and efficient defensive means.

A new Race on AI-driven Cyber Defence posture has begun, which new approach leverages cutting-edge technologies for threat prediction and the proposition and enforcement of appropriate countermeasures. A comprehensive survey is presented on the latest advances on AI-powered predictive systems which identify and respond to the emergence of threats in cyberspace.

A holistic review of state-of-the-art research work on real-time AI-based solution systems to respond to threats has been presented, followed by a comparison and related analysis of the selected works. Finally, research challenges which were sparsely or remotely dealt with by the literature were identified, giving rise to insightful future research directions characterised by a potent potential to upgrade the defensive posture on cyberspace.

As human dependence on digital infrastructures has evolved, these have become critical elements for any society in many application domains, from health and communications to energy and transportation. Automatic systems supervise so that digital systems, connected over the Internet, smoothly perform the services for which they were designed. Decades on, this profound dependency on the use of digital infrastructures has grown exponentially, underpinning the rise of Information Society and paving the way to the so-called Fourth Industrial Revolution.

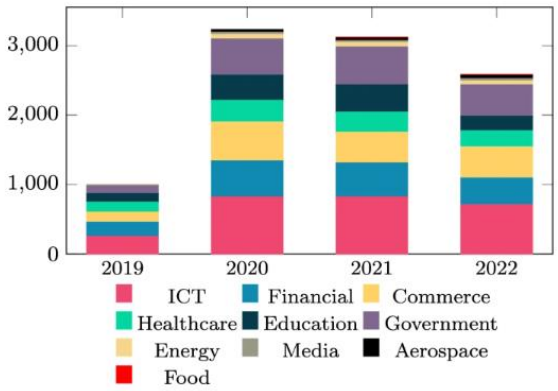

Fig : Integrating AI-driven threat intelligence and forecasting in the cyber security

6.1. Future Trends

Artificial intelligence (AI) technologies will be increasingly sophisticated not only in terms of how easy they are to use, but also how powerful, pervasive, and self-motivated they are. AI can solve more problems than have ever been addressed by computers. Similarly to a human brain, it will be able to reason, interpret, and ultimately become conscious. As systems will exponentially increase the power of AI, our economy will be transformed, and similarly security and other cyber related issues will need to evolve in response to new threats and opportunities. Cybersecurity can benefit from AI in many ways, for example in order to design safer systems, to predict attacks based on collected data, or to develop effective countermeasures. Nevertheless, the evolution of the entire cybersecurity ecosystem as well as new threats based on AI and emerging technologies will have an enormous impact on the capacity of AI to enhance security and to break or exploit it. Rapid advancements in computing technology and data availability have led to a rapid growth in both unstructured data and IOT devices, which accounted for about 90% data available today; it is expected that the huge availability and variety of data will keep growing with an exponential trend, and AI has the potential to effectively analyse it, predict it and inform the users or the owners of these devices. Similarly on the adversarial side, a threat model can derive from the assumption that any new technology will quickly be exploited to create new and more difficult vulnerabilities to counteract than ever before.

Several trends are currently emerging. They point towards a more extended and advanced use of AI, better integration of AI with interdisciplinary knowledge, and better understanding and prediction of the implications of the evolution of AI itself. The arguments reported above pose a challenge related to how AI will evolve against new cyber threats and how this evolution will influence cyber incidents, as well as the impact on economy and privacy. Diplomacy, civil societies and other actors will have an increasingly difficult role in balancing these complex and unpredictable pans. On the other hand, the same AI will offer the opportunity to better understand the implications of its evolution and to better predict them so that proactive actions can be taken to limit the emerging risks. Preventing bad outcomes and supporting the emergence of a “positive evolution” from AI develop proper policies and actions at the appropriate institutional, societal, individual levels will be a fertile ground for the improvement of public awareness and education. This will also imply a change of narrative and coordinated

actions at different levels that foster trust, safety and exchange of knowledge, best practices and capacity-building process aimed at preventing the development of particularly dangerous AI applications.

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