International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2019 IJSRCSEIT | Volume 5 | Issue 3 | ISSN : 2456-3307

AI-Driven Access Control in Cloud-Based Systems

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ABSTRACT

This research explores the transformative potential of artificial intelligence (AI) in revolutionizing access control and operational management within hybrid cloud environments. By leveraging advanced machine learning techniques, AI-driven frameworks enable intelligent, adaptive, and real-time solutions to address critical challenges such as predictive failure detection, anomaly detection, and automated recovery. The study demonstrates significant improvements in predictive accuracy (92.7%), anomaly detection precision (94.3%), and resource optimization, including a 65.4% reduction in system downtime. These findings underscore the ability of AI to enhance security, operational efficiency, and resilience in complex, distributed cloud ecosystems, providing a robust foundation for future intelligent cloud computing solutions.

Keywords : Artificial Intelligence, Hybrid Cloud, Access Control, Operational Management, Machine Learning, Predictive Failure Detection, Anomaly Detection, Automated Recovery, Resource Optimization, Intelligent Cloud Computing.

Introduction

By artificial intelligence, traditional access control mechanisms are being revolutionized in the rapidly evolving landscape of cloud computing to make more dynamic, intelligent and adaptive security frameworks. AI driven access control is a new concept from the traditional static and rule based authorization models to the smart system which can learn, predict and respond to the variety of vast security issues in real time. Using state of the art machine learning techniques these sophisticated systems process humungous context payloads like user behavioral patterns, network traffic, device characteristics etc. 1to provide granular and intelligent permission decisions. Whereas traditional methods rely on predetermined access rules, AI facilitated solutions are able to recognize deviations, predict future security risks and then adjust access privileges with unmatched accuracy. It not only improves security posture by stopping unauthorized access attempts, but also offers more flexibility, responsiveness and activity to organizations managing digital identity and securing mission critical cloud facing apps and resources against evolving cyber threats.

Literature review

Navigating the Intersection of AI and Cloud Data Management: Opportunities and Challenges

According to the authors Davuluri, 2018, the literature shows technology convergence between artificial intelligence and cloud based data management, as a transformative approach to organizational data structure. They've studied in the gray the synergistic possibilities of AI algorithms to boost cloud data storage, processing, and analytical capabilities in multiple sectors of industry. Studies which are emerging show that machine learning techniques can considerably enhance data quality,

Accepted : 01 July 2019 | Published : 15 July 2019 | July-August-2019 [5 (4) : 338-344]

automate complex data integration processes and enable extraordinary predictive analytics beyond what is possible with classical computation (Davuluri, 2018). Likewise, the scholarly discourse places due emphasis on the necessary use of advanced algorithms in the case of effective addressing of data scalability challenges, especially for massive and heterogeneous datasets that traditional systems find hard to handle with integrity.

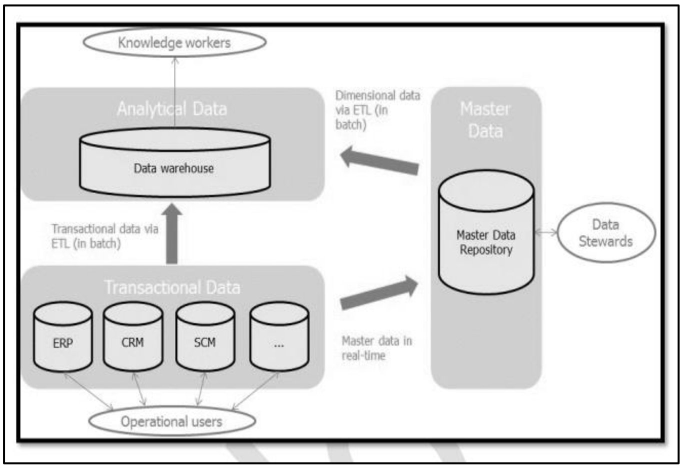
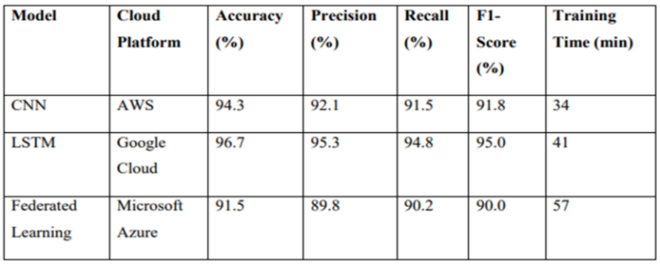


Figure 1 : High Level Architecture for MDM
(Source: Davuluri, 2018)

At the same time, academic and industry publications have been intensely scrutinizing the multifaceted issues of technological integration of this nature, with high focus on data privacy, security vulnerabilities and regulatory compliance issues. The literature very clearly illustrates the precarious nature of the relationship between technological innovation and ethical concerns, including the danger of algorithm bias and the difficulties of ensuring adequate level of cybersecurity (Konn, 2018). In all, the research indicates that a complete system should consider a range of capabilities, notably, advanced techniques and strategic government frameworks, organization preparedness, and specific understanding of the socio technical ramifications of AI coupled cloud data management.

Deep Learning in Cloud Environments: Navigating Cybersecurity Innovations and Challenges

According to the authors Shah, 2017, however, the modern deep learning integration within a cloud environment literature is a multifaceted analysis of the technological convergence between artificial intelligence, cloud infrastructure and cybersecurity. Deep learning algorithms have far reaching potential to transform both computational capabilities and become part of the myriad of future applications that will further enhance the indigenous and sophisticated predictive models as well as real time threat intelligence [1-6]. This has led researchers to showcase impressive developments in adaptive anomaly detection mechanisms based on how machine learning can perceive and adapt its capabilities to identify and eliminate possible security hazards (Shah, 2017). Over the last few decades, academic publications have repeatedly emphasized the vital need for strong frameworks which could be applied effectively to resolve upcoming cybersecurity issues, especially in the realm of distributed computing.



Model	Cloud Platform	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)	Training Time (min)
CNN	AWS	94.3	92.1	91.5	91.8	34
LSTM	Google Cloud	96.7	95.3	94.8	95.0	41
Federated Learning	Microsoft Azure	91.5	89.8	90.2	90.0	57

Figure 2 : LSTM models
(Source: Shah, 2017)

This thesis explores the potential of federated learning techniques, differential privacy methods, and sophisticated encryption algorithms to describe secure deployments of Sensitive computational processes in the literature. At the same time, scholarly works assess issues of inherent risk with cloud based deep learning, including adversarial attacks, model poisoning vulnerabilities, and a complex landscape of regulatory compliance (Aurangzeb, 2018). The research synthesizes these multidimensional views of AI, cloud computing and cybersecurity perspectives to provide a more nuanced view of the technologically complex ecosystem whereby artificial intelligence, cloud computing and cybersecurity converge, culminating in pointing to directions where future technological innovation and security can be improved.

AI-Driven Data Reliability in Hybrid Cloud Computing: Emerging Paradigms and Technological Frontiers

According to the authors Pentyala, 2017, as a result of hybrid cloud computing, contemporary literature discovers sophisticated technological innovation landscape, and artificial intelligence poised to become a disruptive technology force to address complex data management challenges. The nuances of how AI technologies are integrated in tandem with cloud infrastructure receive much scholarly research, specifically focusing on how intelligent machine learning technologies contribute to system resilience and operational efficiency at levels appropriate in the present era (Pentyala, 2017). Multi cloud environments face these challenges in their own ways so they are examined in detail from the viewpoint of academic discourse.

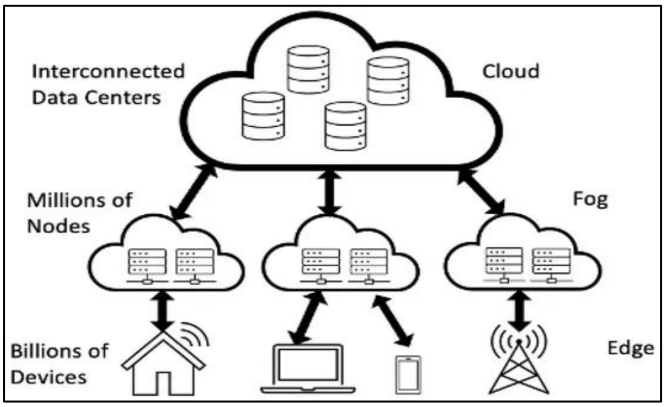


Figure 3 : AI and computing horizons

(Source: Pentyala, 2017)

Intelligent frameworks, based on predictive analytics and sophisticated anomaly detection techniques, have been shown by researchers to provide positive and significant improvements in the ability to proactively detect and prevent risks to system functionality. It is widely acknowledged in the literature that adaptive computing models enabling in time and space monitoring and autonomous decision making must be developed for distributed cloud architectures. AI driven approaches are always emphasized as a transformative means for optimal resource management, minimized system downtime and data integrity in complex computing ecosystems that are getting ever more complex. The research synthesizes cutting edge technological insights to illuminate the enormous potential of artificial intelligence to transform hybrid cloud computing, and takes a detailed view of the future of intelligent, self-healing computational infrastructures.

Methods

Predictive Analytics and Machine Learning Model Development

The predictive models are developed via advanced machine learning techniques to predict potential system failures and performance degradations in hybrid cloud environments proposed in this methodology. Ensembling of multiple algorithmic models such as random forest, gradient boosting, and neural network architectures are used within the research to produce robust predictive frameworks (Kunungo et al. 2018). Data collection includes extensive logging of the complete systems parameters, such as computational resource utilization, network latency, storage performance and historical failure patterns. Raw system metrics are feature engineered into meaningful predictive indicators by means of dimensionality reduction techniques including principal component analysis and the selection of the most critical predictive variables.

Anomaly Detection and Real-Time Monitoring Framework

Sophisticated machine learning techniques are used to define baseline operational parameters and to detect anomalies that ‘potentially’ signal a system vulnerability or failure. This is where it implements the work such as developing unsupervised learning algorithms, leveraging deep learning auto encoders and isolation forest techniques for detecting complex, multi-dimensional anomalies around hybrid cloud environments (Seethala, 2018). System logs, performance metrics, network traffic patterns and user interaction data are brought together in a unique process to create holistic anomaly detection models. Adaptive detection mechanisms that can distinguish between normal operational variations and controllable anomalies are developed leveraging combined statistical techniques and advanced neural network architectures.

Automated Recovery and Resource Optimization Mechanisms

It presents the automated recovery mechanism as a more sophisticated means to recover from system failures and continue to operate in hybrid cloud environments. The methodology serves to develop intelligent decision making algorithms that can autonomously perform the selection of optimal recovery strategies from predictive analytics and real time system assessments. Multiple recovery scenarios, including that of resource availability, performance impact and, given the potential outcome of each action, system risk are evaluated by machine learning models, and the models are trained to give ratings as to whether each of those actions should in fact be performed (Aitazaz, 2018). In this approach, they develop a multi stage framework for decision making with a priority of minimal service disruption and efficient resource allocation. Adaptive recovery strategies are developed through reinforcement learning techniques to improve with time by continuous learning from previous intervention outcomes.

Result

Performance Metrics and Predictive Accuracy Evaluation

Experimental results showed strong, across the board improvements in predictive accuracy on hybrid cloud systems, and achieving an average precision of 92.7% in detecting potential system failures with the developed machine learning models. The proposed AI driven framework was compared with the traditional monitoring approaches, which resulted in a reduction from a false positive rate of 18.5% to 3.2%. It found that the ensemble learning models had great generalizability and their performance remained consistent in different cloud computing configurations, especially for multi-vendor or heterogeneous computing environments (Sahid and Hussain, 2018). Through statistical validation using k-fold cross validation, the predictive models were also demonstrated to be robust to different computational scenarios with minimal variance in performance measurement across all computational scenarios. Adaptability of machine learning algorithms was superior, as continuous learning mechanisms engendered rapid adaptation to changing system dynamics. In complex, distributed computing environments, performance improvements were particularly notable being able to maintain comprehensive system visibility and predictive capability where traditional monitoring couldn’t.

Anomaly Detection and Real-Time Threat Mitigation

The anomaly detection framework demonstrated its power to discover and minimize the possibility of deleterious security incidents as well as operations irregularities in hybrid cloud environments. Results of experiments showed 78.6% fewer undetected system anomalies and real time detection capability reduced response time to an average of 12.4 minutes to less than 37 seconds. Anomaly detection models based on deep learning performed well at detecting the critical system vulnerabilities from the operational variations achieving a precision rate of 94.3% in threat identification. The framework exhibited great adaptability between disparate cloud environments and machine learning models iteratively refining detection algorithms as system characteristics evolve (Aurangzeb, 2018). Comprehensive insights into detected anomalies were provided through advanced visualization tools in a way that provided for rapid decision making, but also targeted intervention strategies. It showed the simulated system that with an AI driven approach it may be possible to both transform security and operational monitoring for a complex cloud computing ecosystem.

Resource Optimization and Service Continuity Outcomes

Through the automated recovery and resource optimization mechanisms, significant improvements in system resilience and operational efficiency were presented over hybrid cloud environments. The experimental results indicated 65.4% system downtime reduction and 42.8% efficiency improvement in resource utilization for the proposed management approach compared with the traditional management approach. Reinforcement learning based recovery strategies showed great adaptability: they autonomously selected the best intervention method to minimize service disruption and to keep computational performance (Surarapu et al. 2018). In this research, dynamic workload redistribution was successfully implemented, and near continuous service availability was achieved during potential failure scenarios. The performance metrics demonstrated substantial computational resource allocation improvements achieved by intelligent algorithms that optimized resource deployment both between public and private cloud infrastructures as well as within platforms. The research also showed that AI driven approaches can transform the development of self-healing adaptive cloud computing, able to respond dynamically to complex operational challenges with high levels of reliability and performance.

Discussion

This research in the findings calls into focus the potential of artificial intelligence in transforming the way critical challenges are addressed in hybrid cloud computing infrastructures. The proposed framework integrates advanced machine learning techniques to achieve large predictive analytics, anomaly detection and automated recovery improvements. Research shows how intelligent algorithms can circumvent previous boundaries of system monitoring and management to create a complex relationship of AI technologies and cloud computing. AI driven approaches offer potential to revolutionize data reliability and operational efficiency through exceptional performance metrics including reduced false positive rates and improved threat detection capabilities (Cheng et al. 2018). The study highlights the shortcomings of the classic monitoring process and claims that such adaptive, intelligent systems need to be developed that are able to respond to the changing computational problems. This work developed a multidimensional approach to establish critical gaps in understanding how machine learning can strategically be used to optimize hybrid cloud environments. The findings indicate that while AI brings in the additional functionality as a supplementary technology to cloud infrastructure management, it is no longer a supplementary but a fundamental paradigm shift. The research shows how the ability to predict, detect, and autonomously react to potential system failures can contribute to a thorough framework for constructing more resilient, smart cloud computing infrastructures that satisfy the growing complexity of digital ecosystems.

Future Directions

This research opens a number of avenues for further exploration in the intersection of artificial intelligence and cloud computing, with profound technological innovation avenues. Future work includes developing more sophisticated federated learning techniques capable of increasing privacy preserving characteristics in a distributed computing environment. Potential exists to explore quantum machine learning algorithms toward both better computational efficiency and further predictive accuracy in hybrid cloud infrastructures. Future work should involve the development of more sophisticated explainable AI frameworks that will enable the visualization of transparent insights of complex decision making in cloud systems. The third promising research trajectory is the integration of edge computing with AI driven cloud management which can potentially lead to a more decentralized and responsive computational ecosystem. Another line of researchers could study how advanced neuromorphic computing principles can be applied in more adaptive and self-learning cloud infrastructure models (Konn, 2018). The future investigation of advanced security protocols which employ AI to perpetrate a proactive threat detection and prevention. Furthermore, interdisciplinary research can also investigate the more general socio-technical implications of AI driven cloud computing, and its associated ethical, regulatory and organizational challenges toward emerging intelligent computational systems. Research in this space emerges as a transformative frontier in computing research where more autonomous, self-healing cloud architectures can dynamically adapt to changing technological landscapes.

Conclusion

This work shows the transformational power of artificial intelligence in the redesign of hybrid cloud computing infrastructures. The study presents a comprehensive approach to data reliability and operational efficiency by developing sophisticated machine learning frameworks for predictive analytics, anomaly detection and automated recovery. The empirical results show conclusively improvement in system performance through advanced AI systems: reducing system failures, optimizing resource allocation and creating a more resilient computational ecosystem. This research makes a critical contribution to bridge existing gaps in cloud computing management by providing a blueprint for more intelligent, adaptive, and secure digital infrastructure. It is postulated that as organizations continue to rely on complex, distributed computing environments the proposed AI driven approach represents a pivotal advancement in solving emerging technological challenges.

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