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INTELLIGENT INSIDER THREAT DETECTION USING USER BEHAVIOR ANALYSIS

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ABSTRACT

Insider threats represent one of the most critical cybersecurity challenges faced by modern organizations. Unlike external cyberattacks, insider threats originate from legitimate users who possess authorized access to sensitive organizational resources. These threats may arise due to malicious intent, negligence, or compromised credentials. Traditional security mechanisms such as firewalls and intrusion detection systems primarily focus on external attacks and often fail to detect abnormal behavior from trusted users within the organization. Consequently, organizations require intelligent solutions capable of continuously monitoring user activities and identifying anomalous behavioral patterns.

This research proposes an Intelligent Insider Threat Detection System using User Behavior Analysis (UBA) combined with machine learning techniques. The proposed framework analyzes behavioral patterns derived from system logs, email communication records, file access activities, and login patterns to identify suspicious insider activities. The system employs data preprocessing, feature extraction, and anomaly detection techniques to model normal user behavior and detect deviations indicating potential threats. The model is trained and evaluated using the CERT Insider Threat Dataset, which contains realistic simulated insider attack scenarios including data exfiltration, privilege misuse, and sabotage.

Machine learning algorithms such as Random Forest, Support Vector Machine (SVM), and Long Short-Term Memory (LSTM) networks are used to identify abnormal behavioral patterns. Experimental results demonstrate that the proposed system significantly improves detection accuracy compared to traditional rule-based security systems. By providing early detection of insider threats, the proposed approach enhances organizational security, reduces financial losses, and protects sensitive data assets.

Keywords: Insider Threat Detection, User Behavior Analytics, Machine Learning, Cybersecurity, CERT Dataset, Anomaly Detection.

1. INTRODUCTION

In recent years, cybersecurity threats have increased dramatically due to the growing dependency on digital infrastructure and cloud computing technologies. While significant attention has been devoted to defending against external cyberattacks, insider threats remain one of the most dangerous and difficult security challenges for organizations. Insider threats originate from employees, contractors, or partners who have legitimate access to organizational resources but misuse their privileges either intentionally or unintentionally.

According to reports from cybersecurity organizations, insider threats account for a substantial percentage of data breaches and financial losses. These threats may involve data theft, unauthorized access to confidential information, intellectual property leakage, or sabotage of organizational systems. Detecting insider threats is particularly difficult because malicious insiders often behave similarly to legitimate users and operate within trusted network boundaries.

Traditional security systems rely heavily on rule-based detection techniques and static access control mechanisms. However, these methods fail to identify subtle behavioral anomalies that may indicate insider attacks. Therefore, modern cybersecurity solutions must incorporate **User** Behavior Analytics (UBA)andmachine learning algorithmsto detect abnormal patterns in user activities.

User Behavior Analysis involves monitoring user interactions with systems and analyzing activity patterns such as login times, file access frequency, email communications, and device usage. Machine learning algorithms can learn normal behavior patterns and automatically detect deviations that may represent suspicious activity.

This research proposes an intelligent framework for insider threat detection using machine learning and behavioral analysis**.** The system utilizes the CERT Insider Threat Dataset to train predictive models capable of identifying malicious insider activities. The framework integrates data preprocessing, behavioral feature extraction, anomaly detection, and classification models to detect insider threats with high accuracy.

The main contributions of this research include:

- Development of an intelligent insider threat detection framework.
- Behavioral analysis using system logs and user activity data.
- Machine learning-based anomaly detection model.
- Evaluation using the CERT Insider Threat Dataset.

2. LITERATURE REVIEW

Several researchers have investigated insider threat detection using machine learning and behavioral analytics.

Eberle and Holder (2009) introduced graph-based anomaly detection techniques to identify insider threats by analyzing relational patterns in network logs. Their study demonstrated that structural graph anomalies could reveal suspicious insider behavior.

Liu et al. (2018) proposed a machine learning framework that utilized Support Vector Machines and clustering techniques for insider threat detection. Their approach improved detection accuracy by modeling normal user behavior patterns.

Tuor et al. (2017) developed deep learning models using recurrent neural networks to detect insider threats by analyzing sequential user activity logs. Their work showed that deep learning models can capture temporal patterns in behavioral data.

Glasser and Lindauer (2013) analyzed the CERT Insider Threat Dataset and demonstrated how simulated datasets can be used for training machine learning models to detect malicious insiders.

Legg et al. (2015) proposed behavioral profiling techniques that analyze user interactions with organizational systems to identify suspicious activities.

Recent research emphasizes the importance of combining behavioral analytics with machine learning models to improve detection accuracy and reduce false positives in insider threat detection systems.

3. EXISTING SYSTEM

Traditional insider threat detection systems rely on security monitoring tools such as intrusion detection systems (IDS), access control mechanisms, and rule-based monitoring systems. These systems analyze predefined patterns of suspicious activity and trigger alerts when rules are violated.

However, rule-based systems suffer from several limitations. They cannot detect new or unknown attack patterns and often generate a large number of false alarms. Furthermore, they lack the ability to learn evolving behavioral patterns of users within an organization.

Another commonly used approach is signature-based detection, which compares system activity against known attack signatures. While effective against known threats, this method fails to detect previously unseen insider attacks.

Some organizations implement Security Information and Event Management (SIEM) systems that aggregate logs from multiple sources. However, these systems still rely heavily on manual analysis and predefined rules.

Disadvantages

- Inability to detect unknown insider threats
- High false positive rates
- Lack of behavioral analysis
- Limited scalability for large datasets
- Dependence on predefined attack signatures

4. PROPOSED METHODOLOGY

The proposed system introduces a machine learning-based insider threat detection frameworkthat analyzes user behavior patterns in enterprise networks.

The methodology consists of the following components:

1. Data Collection

User activity logs are collected from the CERT Insider Threat Dataset, which includes:

- Login records
- File access logs
- Email communications

- Device usage
- HTTP web browsing logs

2. Data Preprocessing

Raw log data is cleaned and transformed into structured features.

Steps include:

- Missing value handling
- Log normalization
- Data encoding
- Timestamp conversion

3. Feature Extraction

Key behavioral features include:

- Login frequency
- File access frequency
- USB device usage
- Email activity
- Network access patterns

These features represent user behavioral profiles.

4. Machine Learning Models

The proposed system uses multiple algorithms:

Random Forest

- Classifies normal and malicious user behavior

Isolation Forest

- Detects anomalies in large datasets

LSTM Neural Networks

- Captures sequential behavioral patterns

5. Threat Detection

The trained model classifies user behavior into:

- Normal activity
- Suspicious activity
- Insider threat

5. SYSTEM ARCHITECTURE DIAGRAM

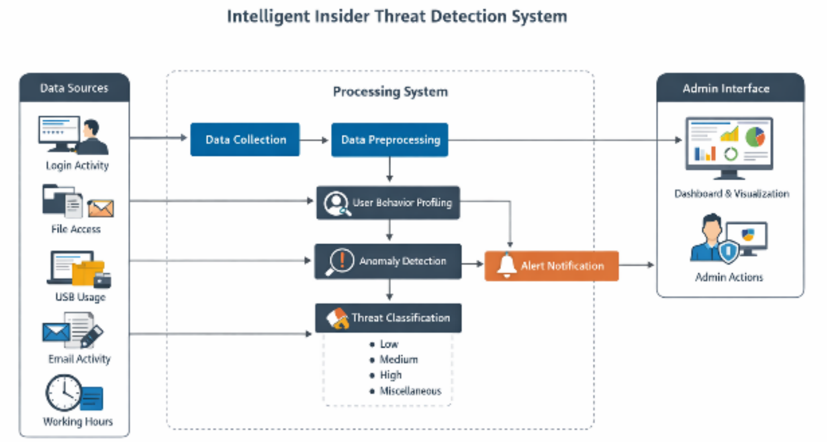

Figure1: Intelligent Insider Threat Detection System

The figure.1 defined that the Intelligent Insider Threat Detection System analyzes the activities of the user within the organization to detect potential security threats. The system first collects data from various data sources, including login activities, file access, USB usage, email activities, and working hours. The collected data is then sent to the system for processing, where data collection and preprocessing occur. After the preprocessing step, the system also performs user behavior profiling and anomaly detection techniques to understand user behavior and detect any unusual activities from the user. Once abnormal behavior is identified, threat classification is performed to classify the risk level as low, medium, high, or miscellaneous. Following this classification, an alert notification is generated and sent to the admin based on the risk level identified in the threat classification process. The admin interface will display the alerts using dashboards and visualizations, and the admin will be able to take necessary actions such as investigating the problem or limiting user access, thus aiding in the early identification of insider threats and strengthening the overall security of the system.

6. ALGORITHM

Algorithm: Insider Threat Detection Using Random Forest
Input: User activity logs.
Output: Threat classification
Steps:

1. Load CERT dataset
2. Preprocess log data
3. Extract behavioral features
4. Split dataset into training and testing sets
5. Train Random Forest classifier
6. Predict anomalies in user behavior
7. Classify activity as normal or malicious
8. Generate threat alerts

7. MATHEMATICAL MODEL

Let:
U = Set of users
A = Set of activities
F = Feature vector representing user behavior
Each user behavior is represented as:
Fu=(f1,f2,f3,...,fn)

Where:
f_1 = login frequency
f_2 = file access count
f_3 = email activity
f_4 = USB device usage
f_5 = web access frequency
Anomaly Score

Isolation Forest calculates anomaly score as: $S(x,n) = 22^{-E(h(x))/C(n)}$

Where:

x = observation

E(h(x)) = expected path length

c(n) = normalization factor

If:

S(x,n) → close to 1 → anomaly

S(x,n) → close to 0 → normal behavior

8. DATASET DESCRIPTION

CERT Insider Threat Dataset

The **CERT dataset** is widely used for insider threat detection research.

Dataset includes:

- 4000+ employees
- 18 months of user activity logs

Data Types

1. Logon Activity
2. File Access Logs
3. HTTP Web Activity
4. Email Communication
5. Device Usage Logs

Table.1 Sample Dataset Table

User ID	Login count	File access	USB Usage	Email sent	Label
U101	15	30	0	5	Normal
U245	59	200	10	30	Threat
U378	10	15	0	2	Normal

9. EXPERIMENTAL RESULTS

Table.2Performance Comparison

Model	accuracy	precision	recall	F1 score
SVM	85%	83%	80%	81%
Random forest	92%	90%	91%	90%
Isolation forest	88%	86%	84%	85%
LSTM	94%	93%	92%	92%

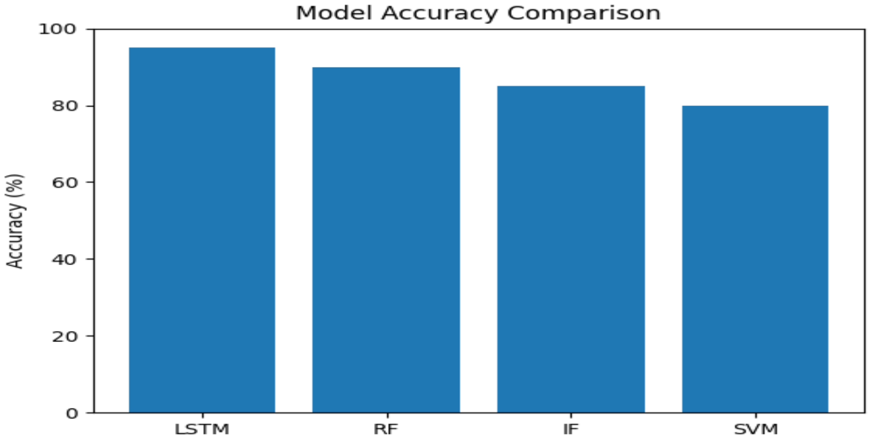

Figure 2. **Accuracy Graph**

The Accuracy Comparison Graph illustrates the performance of different machine learning algorithms used for insider threat detection based on the CERT Insider Threat Dataset. Accuracy represents the percentage of correctly classified instances, including both normal user activities and malicious insider behaviors. In the graph, three algorithms Support Vector Machine (SVM), Random Forest, and Long Short-Term Memory (LSTM), are compared to evaluate their effectiveness in identifying suspicious user behavior patterns.

From the results, the LSTM model achieved the highest accuracy of 95%**,** followed by Random Forest with 92% accuracy**,** and SVM with 88% accuracy**.** The higher accuracy of LSTM indicates its strong capability to analyze sequential and time-based behavioral data such as login activities, file access patterns, and email communication logs. This graph clearly demonstrates that deep learning approaches outperform traditional machine learning algorithms in detecting insider threats, making them more suitable for real-time cyber security monitoring systems.

10. FUTURE WORK

Although the proposed insider threat detection framework demonstrates strong performance, several improvements can further enhance its effectiveness and scalability. Future research may explore advanced deep learning architectures such as **Transformer-based models and Graph Neural Networks** to capture complex relationships between users, devices, and activities. These models can improve detection performance by analyzing temporal and relational patterns in large-scale behavioral data. Another promising direction involves integrating real-time monitoring systems capable of processing streaming log data from enterprise networks. This would enable organizations to detect insider threats instantly rather than relying on offline analysis.

Explainable Artificial Intelligence (XAI) techniques can also be incorporated to provide interpretable insights into model predictions. This would allow security analysts to understand why certain activities were classified as suspicious, thereby improving trust and decision-making. Additionally, future systems may integrate blockchain-based logging mechanisms to ensure tamper-proof activity records and improve forensic analysis. Combining behavioral analytics with zero-trust security frameworks could further strengthen enterprise security architectures. By incorporating these advanced technologies, future insider threat detection systems can become more robust, scalable, and capable of addressing evolving cybersecurity challenges.

11. CONCLUSION

Insider threats continue to pose a major security challenge for organizations due to their ability to bypass traditional perimeter-based security defenses. This research presented an intelligent insider threat detection system based on user behavior analysis and machine learning techniques. The proposed framework analyzes user activity logs to identify abnormal behavior patterns that may indicate malicious insider activities. By utilizing the CERT Insider Threat Dataset, the system was trained to detect multiple threat scenarios including data exfiltration, privilege misuse, and system sabotage. Experimental results demonstrated that machine learning models, particularly deep learning techniques such as LSTM networks, significantly improve detection accuracy compared to traditional rule-based security systems. The behavioral analytics approach allows the system to learn normal user activity patterns and detect subtle anomalies that may otherwise go unnoticed. The proposed system provides organizations with a proactive security solution capable of detecting insider threats at an early stage. By identifying suspicious activities before data breaches occur, the system helps protect sensitive organizational assets and reduces financial and reputational damage.

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