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An Efficient Blockchain-Based Active Learning Semi-Supervised Smart Contracts in Ethereum Blockchain Traceable Food Supply Chain

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Abstract: The lack of food traceability has resulted in significant issues such as product recalls, public discontent, and concerns about contamination in previous instances. This study examines the traceability process using efficient stochastic mathematical frameworks and the concept of transparency using forthcoming Blockchain technology. Due to the rising popularity of blockchain technology, there has been a rapid growth in the number of smart contracts. Implementing efficient smart contract vulnerability detection is hindered by a significant obstacle: the need for more labeled data in the present domain. Classical active learning relies on a small quantity of tagged information for model training. This research proposes Confidence Interval Ensemble Learning Traceability (CI-ELT) to address these problems. CI-ELT introduced a new approach called the Active and Semi-Supervised Network framework. This structure addresses the limited labeled code information found in real-world smart contract threat detection jobs. In stochastic optimization, CI-ELT demonstrates a comprehensive system in a theoretical manner. CI-ELT used Blockchain technology to securely record the data of manufacturers, merchants, and suppliers, ensuring openness and traceability throughout the whole supply chain. The findings indicate that CI-ELT improves the effectiveness of the most advanced Intrusion Detection Systems (IDS). Compared to the existing Intrusion Detection Systems (IDSs), it attains a detection accuracy of 93.68%, a false alarm rate of 1.25%, and an F1-measure of 2.52%.

Keywords *- Active Learning, Ethereum Blockchain, Smart Contracts, Supply Chain*

1. Introduction

Active getting to knows incorporation into Ethereum blockchain smart contracts raises troubles with computing performance and fuel expenses [1]. Active learning algorithms are useful resource-in depth, which can lead to better transaction prices and make a large-scale implementation of the device impractical [2]. In addition, the mastering model's accuracy and dependability are called into question by the ingenious contracts' semi-supervised nature, which relies upon on partly categorized facts and will result in misclassifications and worse traceability [3]. The clean operation of smart agreements in an in depth food supply chain is in addition complicated by Ethereum's scalability problems [4]. For conditions wherein real-time traceability is crucial, the platform's latency and transaction throughput regulations can postpone or save you the proposed device from responding quick enough [5]. The lively getting to know version inherent inside the clever contracts is already complicated enough without adding the unpredictability and volatility of the food manufacturing technique, which reasons demand and deliver to range [6]. The dependence on blockchain generation raises protection problems for the reason that, although it improves traceability, it adds feasible weaknesses [7]. A breach within the blockchain's safety might disrupt the whole machine for tracking food from farm to divergence, and knowing contracts aren't safe both [8]. To shield the cautioned solution from dangerous attacks and unanticipated weaknesses, sufficient safeguards must be set up [9]. While the idea of the use of blockchain generation in conjunction with active studying to create traceable food supply chains is an interesting one, there are a number of obstacles to triumph over while placing this plan into action in the Ethereum blockchain environment [10]. For the recommended machine to be a reliable and effective tool for improving food supply chain traceability, it is essential to remedy problems with computational efficiency, scalability, security, and the dependability of semi-supervised studying [11].

For a traceable food supply chain on the Ethereum blockchain, it is essential to apprehend the modern methodologies and the troubles they carry to assemble an effective blockchain-primarily based active learning semi-supervised ingenious contract system [12]. A powerful technique includes incorporating active studying algorithms into smart contracts. This allows the version to constantly improve its categorization accuracy through querying and getting to know from relevant information [13]. Although this approach indicates promise for boosting food supply chain traceability overall performance, it has problems with computing efficiency and transaction prices. Active learning algorithms are aid-

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extensive, which can make gas extra high-priced and reduce the answer's scalability and fee-effectiveness [14]. Another essential method to the use of both labelled and unlabelled records for education is to contain semi-supervised gaining knowledge of into clever contracts [15]. However, there are issues with the accuracy and dependability of the fashions resulting from the dependence on in part labeled records. Training is already difficult sufficient without having to account for the ever-converting situations and varied data assets that make up the food supply chain [16]. Furthermore, in conditions in which real-time traceability is essential, the inherent scalability difficulties of Ethereum greatly avoid the clean execution of smart contracts. Potentially hindering the gadget's responsiveness in a massive-scale, dynamic supply chain context are restrictions in transaction throughput and latency. With blockchain-based answers, security is of the utmost importance. While blockchain technology improves audit trails, it poses new security dangers, consisting of flaws in smart contracts and threats to the blockchain itself. Maintaining the integrity of the traceable food supply chain calls for making sure that the proposed machine is powerful and resilient against numerous safety threats. To finish, to construct an effective blockchain-primarily based solution for traceable food supply chains within the Ethereum ecosystem, it is vital to comprehend and solve the troubles associated with active and semi-supervised mastering, scalability, and safety.

- The studies challenge goals to deal with the issue of defective food traceability by utilising blockchain technology and powerful stochastic mathematical frameworks. The research objectives to deal with food supply chain troubles which includes recollects, public dissatisfaction, and infection concerns.
- The research focuses on the domain's lack of labeled data to efficiently discover smart contract vulnerabilities. With the Active and Semi-Supervised Network design, the paper proposes Confidence Interval Ensemble Learning Traceability (CI-ELT) to overcome conventional active learning's limitations in identifying smart contract threats in practice.
- The research uses blockchain technology, namely the Ethereum blockchain, to ensure food supply chain transparency and traceability. CI-ELT plans to discreetly record producer, retailer, and provider data to make traceability data more reliable. Our long-term goal is to improve food supply chain transparency and safety.

The remainder of the paper is organized like the following: In Section II, it is examined the existing literature on Ethereum Blockchain-Based Active Learning Semi-Supervised Smart Contracts, exploring the present status of the topic and pinpointing areas that require more investigation. Section III mathematically discusses on Confidence Interval Ensemble Learning Traceability (CI-ELT). Experiment findings, analysis, and comparisons to prior approaches are detailed in Section IV. Chapter V presents the final results.

2. Literature Review

The paper summarizes a wide variety of research projects that are focusing on the convergence of modern technologies, with an emphasis on the interdependent nature of blockchain, AI, and the IoT, as well as their revolutionary uses in many fields.A thorough overview of blockchain technology's integration with artificial intelligence (BT-AI) is proposed by Salah, K et al [17]. It does a literature search, compiles data, and provides a brief overview of new protocols, apps, and platforms that aim to bridge the gap between blockchain and AI. Finding and discussing unanswered research questions related to using blockchain technology to improve AI capabilities and applications is the primary goal of the research.

An integrated strategy integrating blockchain and the internet of things (IoT) is proposed by Torky et al [18]. for precision agriculture. It presents new blockchain models (NBCM) to solve problems in agriculture caused by the Internet of Things (IoT) and undertakes a thorough survey. While examining the roles of blockchain platforms in supply chain management, crop and livestock management, and cybersecurity, it delves into the privacy and security concerns that have currently prevented blockchain-IoT systems from being fully implemented in precision agriculture.

Examining the problems with IoT machine security, Mohanta, B. K. Et al [19]. Spotlight how traditional safety features fall brief. To restore the security holes determined, it investigates the opportunities of Blockchain, Machine Learning (ML), and Artificial Intelligence (ML-AI). Examining those technologies' efficacy in bolstering IoT security, the paper lays out research boundaries for capability improvements on this area.With the aim of addressing useful resource regulations, enhancing availability, and preventing insider threats, Tukur et al. (Y. M.) [20] offer a blockchain-enabled anomaly detection approach (B-ADT) for IoT structures. Through the utilization of edge computing, the technique improves records integrity even as lowering bandwidth demands and latency. For the Internet of Things (IoT) to be a success, it's miles crucial that sensor data be correct and with ease to be had. This is executed by using combining dispensed part computing with series-based totally anomaly detection. Assessing the method using datasets from actual IoT systems proves its efficacy. A traceability system (TS) for global on line exchange is one approach that Lee, H. Et al [21]. Suggest the usage of to combat counterfeit products. It lets in purchasers to check the product's legitimacy earlier than shopping for it by using securely exchanging precise product data with others worried inside the supply chain. By giving clients the gear to spot and document forgeries, this approach builds agree with, cuts down on monetary losses, and forestalls the spread of counterfeits, as proven within the pilot investigation. A steady and transportable manner to integrate Blockchain with Industrial Internet of Things (IoT) systems is offered by using Mazzei, D et al [22]. In their studies on an Industrial Blockchain Tokenizer (IBT). The IBT collects facts from diverse gadget the usage of a business facts acquisition unit, applies part filtering, after which sends it to any Blockchain platform. The gadget's capacity to shape bridges and generate everlasting digital twins; for use in business Internet of Things (IoT) programs has been proven complete testing in supply chain scenarios.

With its established effectiveness, CI-ELT stands out as an innovator in tackling crucial difficulties and advancing the integration of blockchain in transformative applications. This is because the technological landscape is continuing to grow, and CI-ELT has demonstrated their effectiveness.

3. Confidence Interval Ensemble Learning Traceability (CI-ELT)

Using efficient stochastic mathematics frameworks & Blockchain technology, the paper proposes a new solution to the pressing problem of insufficient food traceability, which causes product recalls & public concerns. A novel Active and Semi-Supervised Network framework, CI-ELT, is developed to overcome the difficulty of limited labelled data in intelligent contract vulnerability detection. Secure data recording throughout the supply chain is made possible by CI-ELT's use of Blockchain technology, which increases transparency. Stochastic optimization focuses into the theoretical underpinnings of CI-ELT, revealing its all-encompassing methodology. Fig 1 illustrates a revolutionary solution; the Ethereum Blockchain Accessible Food Supply Chain aims to transform the food supply chain management, tracking, and integrity assurance processes. Advanced learning algorithms, smart contracts, and blockchain are a few of the latest developments that are utilized in this extensive ecosystem to improve security, transparency, and traceability. Decentralized and dispersed ledger technology, the Ethereum blockchain, is the inspiration of the machine. Due to this layer's stable and unchangeable file of transactions and information, the whole tracked food supply chain can be constructed upon.

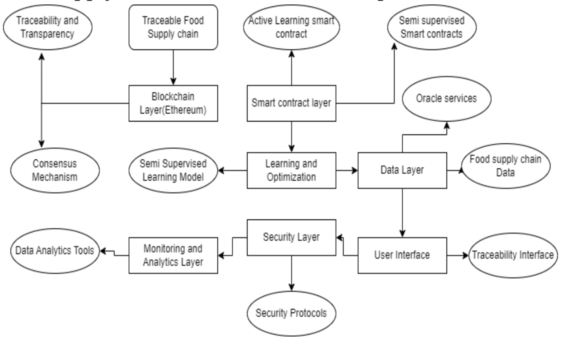

Fig 1. Ethereum Blockchain Traceable Food Supply Chain

To create some straightforward and tamper-proof surroundings, Ethereum strong infrastructure allows for the creation and implementation of smart contracts. To ensure every person in the community is of the same opinion that transactions are legitimate; the blockchain layer uses a consensus mechanism. The traceable supply chain for food is made extra steady and dependable with this approach, which prevents fraudulent operations and continues the recorded facts intact. One manner to automate implementing commitments inside the device is through clever contracts, which might be contracts that self-execute with coded terms. Supply chain operations are made more efficient and less reliant on middlemen due to the Smart Contract Deployment layer. For the sake of preserving consistency and reliability, smart contracts are crucial. An unparalleled degree of transparency and traceability is made possible all the manner through the supply chain for food by means of the blockchain layer. From the origin of the assets to the very last buyer, the blockchain records every transaction. Because of this openness, troubles like fraud or contamination may be speedy diagnosed and resolved, which in turn increases self-belief amongst stakeholders. By adding active schooling and semi-supervised shrewd agreements to the blockchain infrastructure, the Smart Contracts Layer expands its capabilities. By analysing statistics in real-time, active studying algorithms are capable of make regular enhancements. It uses algorithms for device studying to look for patterns, foresee issues, and provide solutions for optimization. Machine studying algorithms and human input work collectively in semi-supervised smart contracts. This system is optimized the use of the Learning and Optimization layer's lively gaining knowledge of algorithms with semi-supervised studying models. Through iterative system optimization and widespread performance profits, these algorithms are able to study from the large quantities of records produced by the supply chain. Important data referring to the food distribution machine is saved within the Data Layer. For the blockchain to be accurate and trustworthy, Oracle offerings need to be used to import information from the actual global.

Interaction between users and the traceable supply chain for food is made easier by the User Interface layer. By implementing stringent security standards, the Security Layer guarantees the safety of the entire system. Understanding how well the traceable supply chain for food is doing is possible because to the Monitoring & Analytics Layer's use of sophisticated data analytics technologies. Improve decision-making and system efficiency with data-driven insights provided by monitoring solutions that analyse critical indicators, discover patterns, and measure overall system performance. Secure, transparent, and intelligent, the Ethereum Blockchain Identifiable Food Supply Chain incorporates blockchain technology, smart contracts, with advanced learning algorithms.

$$EB = \frac{1}{O}\sum_{j=1}^{O}\left(\sigma\left(\sum_{k=1}^{N} tani\left(X_{jk}.y_j + c_{jk}\right)\right) + \frac{corr(\hat{z},z)}{\sqrt{var(\hat{z}).var(z)}} + \lambda.\|X\|^2\right) \quad (1)$$

A number of important variables and terms are included in the detection accuracy equation (1), EB. With a feature vector y_j describing each occurrence, the total number of examples in the dataset is denoted by O. Connected to input characteristics using weights X_{jk} and biases c_{jk}, the hidden layer of the neural network has N neurons. The neural network becomes nonlinear due to the activation functions σ(sigmoid) and $tani$ (hyperbolic tangent). The predicted $\hat{z}$ and true labels z are normalized by their variances, and the Pearson correlation value among them is measured by the correlation term. Large weights are penalized through the squared L2 norm, and the regularization term $\lambda.\|X\|^2$ limits the impact of this term. When applied to a neural network, the equation (1) encapsulates the complexities of detection accuracy through the use of deep learning principles and regularization.

$$GBS = \frac{f^{\sum_{j=1}^{O}(\beta_j.Y_j)+\delta.C+\alpha.T+\sum_{j=1}^{O}\sum_{k=1}^{O}(\gamma_{jk}.y_j.y_k)}}{1+f^{\sum_{j=1}^{O}(\beta_j.Y_j)+\delta.C+\alpha.T+\sum_{j=1}^{O}\sum_{k=1}^{O}(\gamma_{jk}.y_j.y_k)}} \quad (2)$$

The equation (2) to the false alarm rate (GBS) captures the model's complexity through the distinct roles played by each variable. Some of the variables are O, which stands for the number of characteristics in the model, Y_j, which represents the jth characteristic in the relevant features vector, and β_j, which stands for the weight or effect of the jth characteristic in the ensemble training method. The effect of semi-supervised learning, which takes into consideration limited labeled data, is denoted by T, whereas C denotes the effect of block chain computing on traceability. The term γ_{jk} adds complexity using inter-feature relationships by capturing non-linear interactions among features y_j and y_k. For the purpose of detecting threats to smart contracts, the overall equation (2) uses a logistic function to guarantee that the result has a probability between zero and one.There is an immediate need for revolutionary solutions, which portrays the complex problems inherent in the conventional rice supply chain system. There are many problems with the traditional method of managing the supply chain for rice crops, which makes it less efficient and less financially viable. Taking advantage of the cyclical changes in rice prices is a common tactic for investors, which leads to a number of problems. Significant economic losses are caused by the practice of releasing rice during off-season peaks after keeping it during abundant cheap seasons. As an end result, governments and farmers are hesitant to interact much in rice cultivation and imports due to the unpredictable costs. Traditional strategies of presenting rice have a reputation for being unreliable and difficult to tune, which has brought about vast mistrust. Governments have attempted to step in by enacting regulations, the trouble of lack of accountability and traceability, together with a basic loss of believe, remains a huge obstacle. Regulators have failed to accurately put into effect reforms to the traditional agriculture supply chain. The Figure 2 shows how hard it is to enforce trade due to the current gadget's loss of transparency and the mistrust amongst crucial players. It is crucial to enforce a new gadget for dealing with the rice supply chain that is extra honest and open to restore those systemic issues. To control expenses and alleviate issues with the existing supply chain machine, blockchain technology is a great fit due to the fact to its inherent properties including decentralization, transparency, and traceability. The automation of enterprise procedures and consensus strategies is predicated heavily on the mixing of smart contracts into the Blockchain ecosystem. Increased confidence and protection among supply chain contributors is finished thru using these smart contracts, which validate transactions and selection-making techniques. With the motive of verify transactions and make choices, the Blockchain-based totally gadget of agriculture uses consensus protocols. This lets in for the seamless inclusion of clean blocks to the chain. By working in tandem, ingenious contracts consensus protocols improve self-belief and offer realistic, low-value answers to urgent troubles. The distributed nature of Blockchain makes it perfect for protective rice agricultural statistics from unauthorized access, change, or erasure. The supply chain is blanketed due to the fact nobody apart from authorized customers can get admission to or exchange any of the information saved inside the machine. Building a dependable system to music rice plants has never been easier than the usage of Blockchain generation, because of its distributed ledger and safety capabilities.

The problems shown in Figure 2 can be solved by establishing a trustworthy and dependable ecosystem in the rice the supply chain using Blockchain technology. By addressing current problems and introducing new ones, this technology has the potential to make the rice supply chain even more transparent and reliable. As shown in Figure 2, the use of Blockchain technology has the potential to revolutionize rice crop management, leading to a future that is more secure, resilient, and economically feasible.

$$F1 = \frac{\sqrt{x^U.(\beta.Q^2+\gamma.S^2).f^{-\delta.(\theta^U.\theta)}}}{\delta.\left(\sqrt{x^U.\beta.Q}+\sqrt{x^U.\gamma.S}\right)+f^{-\delta.(\theta^U.\theta)}} \quad (3)$$

The equation (3) evaluates the smart contract danger ($F1$) detection method in the block chain-based tracked food supply chain using matrix functions, vectors, and hyperparameters. In many experiments or situations, the accuracy and recall values are represented by the vectors Q and S, respectively. The weight vector x determines the relative relevance of precise cases, which in turn influences the total impact of keep in mind and precision. The have an effect on of false positives and false negatives, as well as non-linear connections, are managed the use of hyperparameters δ, γ, and β. This matrix, denoted as θ, can seize the dynamic interactions between take into account and precision and allow complicated changes depending on numerous parameters. The intricate courting among these variables, together with their matrix with vector representations, lets in for a comprehensive and tailor-made assessment, which mirrors the complex clever agreement safety detection mechanism and its efficacy within the tracked foods supply chain.

$$Q = \frac{x_{EB}.EB + x_{GBS}.(1-GBS) + x_{F1}.F1 + DG_{total}}{x_{EB} + x_{GBS} + x_{F1} + 1} \quad (4)$$

Q stands for the complete CI-ELT device performance in the performance equation (4). The detection accuracy (EB), false alarm rate (GBS), and F1-degree (F1) are weighted with the aid of the x_{EB}, x_{GBS}, and x_{F1}, respectively. Each metric's weight within the wellknown assessment is decided via its cost. Every metric is given identical weight while considering uncertainties the use of the global interval of self-belief factor DG_{total}. The end result is normalized within the denominator and aggregated inside the numerator the use of the weighted contribution of each metric and their corresponding self-assurance intervals. The suggested CI-ELT system for chain-primarily based studying of semi-supervised smart settlement development inside the Ethereum blockchain for a tracked food supply chain provides a detailed evaluation via the equation (4), emphasizing the importance of every overall performance parameter.

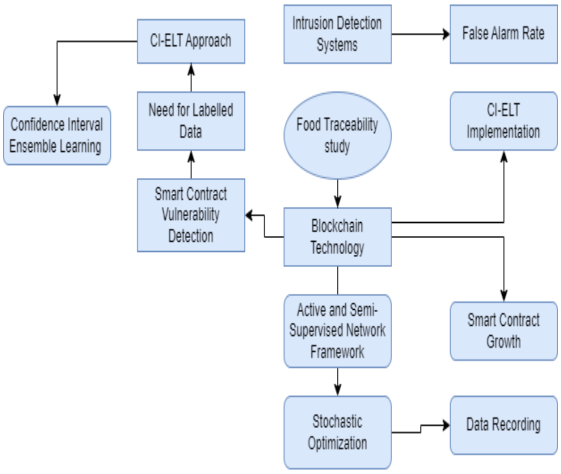

Fig 2: Confidence Interval Ensemble Learning Traceability (CI-ELT)

Confidence Interval Ensemble Learning Traceability (CI-ELT) is an all-encompassing system that aims to improve food traceability by integrating modern technologies including Smart Contracts and Blockchain, as shown in Fig 2. Blockchain technology is the bottom of CI-ELT. Information is each transparent and unchangeable due to the fact to this distributed ledger this is difficult to modify. A shared, secure, and demonstrated document of the whole food supply chain is cooperatively contributed to through producers, stores, and providers. Automating and imposing agreements inside the traceability framework is made feasible by using clever contracts. By carrying out established regulations while specific criteria are happy, Smart Contracts growth transaction performance and reduce fraud threat and their adoption is on the upward thrust. CI-ELT employs a strong structure that merges Active and Semi-Supervised Network methods. This sparkling technique improves foods product tracking by means of utilising supply chain data, which ensures precision and dependability. For an extra precise and progressed traceability method, the CI-ELT framework uses Stochastic Optimization techniques. By utilizing stochastic fashions, the system is able to alter to converting and unpredictable instances inside the supply chain, ensuring the best possible traceability in lots of complicated conditions. A complete records recording mechanism is the coronary heart of CI-ELT. With the purpose of record every vital step of the technique of supply chain management, producers, outlets, and providers all work collectively to build a deep database. These captured data are maintained securely at the Blockchain and shape the premise of traceability. As a precaution against the risks that might be lurking in Smart Contracts, CI-ELT has a devoted module to discover these vulnerabilities. Thus, the automatic contracts controlling transactions are stored safe from exploitation or illegal get entry to. It is important to have labelled facts to improve the CI-ELT setup. This annotated records are used to educate the machine to stumble on supply chain weaknesses, outliers, and styles. One important part of the CI-ELT approach is Confidence Interval Ensemble Learning. This complicated method contains a fixed of models, or ensemble, that offers forecasts in conjunction with confidence intervals. A progressed and greater precise system for monitoring may be finished in this way. To preserve the traceability machine safe from intruders and different dangers, the CI-ELT framework uses Intrusion Detection Systems. The safety of the food distribution device is elevated with this greater safeguard. Detection Accuracy and False Alarm Rate are two metrics which might be a part of the CI-ELT method which are used to measure and customize the system's overall performance. Continuous improvement and adaptableness to rising difficulties within the food provenance panorama are ensured with the aid of this iterative comments loop. A progressive and complete approach for monitoring food origins, Confidence Interval Ensemble Learning Traceability (CI-ELT) makes use of modern techniques to build a green, transparent, and safe supply chain. To enhance the accuracy of traceability, this new CI-ELT device uses ensemble gaining knowledge of to create a synergy among numerous models. The use of Confidence Interval Ensemble Learning strengthens the food traceability surroundings' capacity to face up to new threats and vulnerabilities via developing a resilient system that can alter to converting conditions in the supply chain.

$$F = \frac{\sqrt{E.(1-G_{BS})}.(1+F1) + \ln\left(\frac{E+(1-G_{BS})}{E.F1+G_{BS}.F1}\right)}{\sin(E).\cos(G_{BS}) + \sqrt[3]{E^2+(1-G_{BS})^2}.\tan(F1) + dtd(E+G_{BS}+F1)} \quad (5)$$

The performance equation (5) includes F as the general metric for the performance of the counseled Confidence Interval Ensemble Learning Traceability (CI-ELT) machine in detecting threats to clever contracts. The G_{BS} represents the frequency of false alarms, E represents the accuracy in spotting threats, and F1 represents the harmonic equilibrium of recall and precision in chance identification. To seize the complicated correlations among those vital performance measurements, complicated mathematical expressions are used, which encompass square roots, logarithms, as well as trigonometric features. Taking into account the intricacies of blockchain-based totally tracked food supply chains and the characteristic of the CI-ELT device in improving visibility and protection in such a surroundings, the equation (5) offers a complete and multidimensional assessment.

$$Z = \sum_{j=1}^{O} X_j . \left[i_j(Y) + \gamma . \left(1 - \frac{1}{1+f^{-\delta.(\alpha.\sigma.Y)}} \right) \right] + \beta . (1 - \epsilon) . \sqrt{\frac{\pi}{2}} . \frac{1}{\sqrt{1+f^{-\alpha.\sigma}}} \quad (6)$$

The output labels, which show if a smart contract's code is malicious or not, are represented by the equation Z. The ensemble of hypothesis functions is contained in the total terms $\sum_{j=1}^{O} X_j . \left[i_j(Y) + \gamma . \left(1 - \frac{1}{1+f^{-\delta.(\alpha.\sigma.Y)}} \right) \right]$. The $i_j(Y)$ represents the prediction of the jth hypothesis, and X_j is the confidence weight assigned to it. The use of a sigmoid function to include information from unlabelled information is introduced by the γ in semi-supervised learning. The active learning parameter β controls the exploration-exploitation trade-off, while the labelling unpredictability of active learning is represented by ϵ. The parameter of the non-linear function of activation is represented by δ, and the blockchain accountability factor for securely capturing data is $\alpha.\sigma.Y$. Using a Gaussian distribution, the last term $\beta.(1-\epsilon).\sqrt{\frac{\pi}{2}}.\frac{1}{\sqrt{1+f^{-\alpha.\sigma}}}$ improves ensemble learning by means of stochastic optimization. Using a wide variety of inputs and approaches, the equation (6) captures a complex model for detecting threats to smart contracts, which improves their accuracy and robustness.

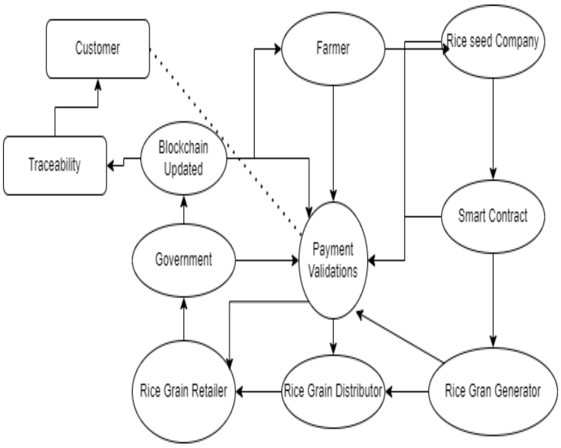

Fig 3. Framework for Rice Crop Supply-Chains Traceability using Blockchain

Fig 3 shows the new and comprehensive structure for the rice crop supply network that uses the most advanced blockchain technology. Delivering high-quality rice from farm to divergence is ensured by this framework, which solves important industry concerns like safety, dependability, efficiency, and transparency. The suggested solution revolves around blockchain, a distributed ledger technology that is both secure and impossible to manipulate. All events involved are capable of see the entire cycle of the cultivation of rice because of this innovative approach's open shape. From planting seeds to remaining the deal, the framework is there every step of the manner, encouraging transparency and responsibility all the way through the supply chain. All links in the rice supply chain are made obvious using blockchain generation. Anyone involved within the supply chain, from wholesalers to buyers, can follow the rice it purchases and consume to its final vacation spot. Building purchaser confidence and permitting knowledgeable decision-making are each significantly greater by means of this stage of transparency. The recommended shape is predicated heavily on smart contracts to protect financial dealings. The blockchain will mechanically document the price details and transaction records each time a farmer purchases seedlings from a grain dealer. These data will be immutable, unchangeable, and untouchable because of clever contracts. All financial transactions during the supply chain might be recorded in an unalterable and steady ledger. Due to its allotted ledger era, the blockchain reduces the likelihood of supply chain interruptions and removes the possibility of one factor of failure. Smart contracts make sure the safe execution of all transactions, from seed purchases to rice distribution. The gadget's universal stability is advanced and the impact of any vulnerability is mitigated by way of this decentralized method. The counseled framework can assist stores, who play a crucial function inside the chain of supply, recognize wherein their seeds came from, how tons' food it harvested, what statistics was accrued from the rice turbines, and what records changed into bought from distributors. Merchants are able to make better judgments concerning the legitimacy and best of the rice that buy due to the fact to this precise stage of tracking, which is good for all people involved. Another essential reason of the deliberate device is to make it less difficult for the government to behavior audits and oversight. By monitoring transactions inside the food supply chain using the blockchain, authorities can locate any illicit developments or activity and affirm that each one events are following the guidelines. This function improves the environment's potential to provide and distribute rice even as concurrently strengthening regulatory efforts. The capability for blockchain era to enhance the cutting-edge method for producing rice plants is illustrated schematically in Fig 3.

The suggested framework improves the rice supply chain as a whole by bringing transparency, security, & efficiency, which are beneficial to all parties involved. A future where rice manufacturing and delivery are more dependable, secure, and transparent is within reach with this new strategy. Figure 4 shows how blockchain technology has revolutionized rice supply chains by providing stakeholders with unmatched security, traceability, and transparency. The figure 4 depicts the technological advancements that will have an impact on rice production in the future. The study's innovative architecture, CI-ELT, stands for Confidence Interval Ensemble Learning Traceability in the equation (7). The variables of the model that need optimization are represented by the θ.

$$CI - ELT = \arg max_{\theta}\{M(\theta, E_{label}, E_{unlabel}, N_{IDS}) + \lambda S(\theta) + \delta U(E_{blockchain})\} \quad (7)$$

The combined loss function, which uses both labelled and unlabelled data to train the Intrusion Detection System, is denotedas $M(\theta, E_{label}, E_{unlabel}, N_{IDS})$. The regularization is controlled by the λ, which finds a middle ground between the model's complexity and its data-fitting ability. Complex models are penalized by the regularization term $S(\theta)$. To improve transparency and traceability throughout the supply chain, the blockchain-based traceability mechanism, represented by $\delta U(E_{blockchain})$, is affected by the δ. This mechanism guarantees the secure capturing of data in the blockchain from producers, merchants, and suppliers. Maximizing the combined objective is the ultimate goal, which is achieved by considering the Intrusion Detection System's performance, the complexity of the models, and the advantages of blockchain-based traceability.

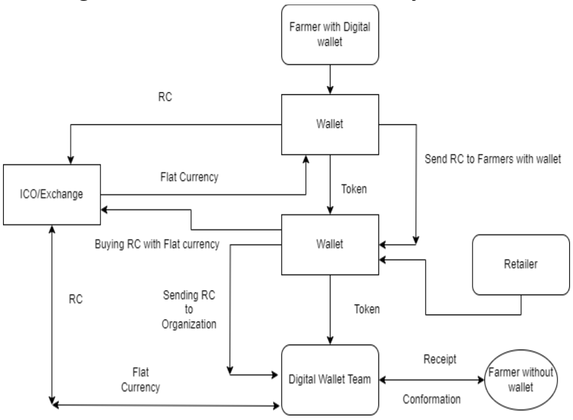

Fig 4: Ecosystem for Decentralized Rice Crop Managing Using RC Token

A pioneering solution in the dynamic world of crop production, the RC token introduces a safe, transparent, and auditable ecosystem for managing rice crops. Fig 4, depicting a decentralized system that reimagines the roles of participants and authorities in the rice supply chain, are crucial to this revolutionary framework. The RC token is the essential component that strengthens the system against fraud and promotes an atmosphere of trust & efficiency. The RC coin permits fractionalized purchases, letting users acquire according to their needs, with a predefined total quantity of 500 million tokens, every having an intrinsic value of USD 100. With the option to purchase portions as 0.1 RC for USD 10, these democratize of access is in line with the spirit of inclusivity. This adaptability equally applies to the payment methods, which include a wide variety of cryptocurrencies and fiat currencies like USD, EUR, PKR, BTC, BNB, ETH, & many more. The decentralized character of blockchain technology means that buying RC doesn't cost anything and merchants get the same advantages and token value.

The RC coin is built on top of the Ethereum blockchain, which is already well-established and secure, since it is an ERC-20 standard. As a demonstration of the democratic values that drive the RC ecosystem, the inaugural distribution took place through an inaugural Coin Offering (ICO). Merchants' digital wallets automatically replenish when consumers purchase RC. Retailers are able to purchase rice from distributors through this simplified approach, which promotes a mutually beneficial relationship between all parties involved. Two different ways for farmers to get their money are included into the system. In the first case, farmers who are comfortable with generation and feature digital wallets get their bills in RC. Coins can then be exchanged for fiat currency through a preliminary coin supplying (ICO) trade, opening the door to greater conventional economic structures. The second situation depicts farmers who pick to be extra worried inside the technique. When farmers pay the use of RC, the digital pockets's team acts as a middleman and set up for the cryptocurrency to be converted into fiat money through an ICO change. Because of its adaptability, this technique can accommodate a huge variety of farming alternatives by way of bridging the space among the physical and digital realms. The suggested blockchain architecture manages to be each obvious and personal, making it a hybrid marvel.

Governments have access to verified, auditable, and verifiable transactions, while stakeholders like merchants, farmers, distributors, and rice mills can keep their data private. Maintaining the security and secrecy required by many stakeholders is achieved by this strategic position, which guarantees compliance with regulations. The RC token-driven ecosystem for rice crop management is a complex web of interdependent technological, agricultural, and financial components, as shown in Figure 5. This decentralized model is a shining example of innovation because it prevents malpractices while simultaneously bringing about a new age of accessibility, collaboration, and efficiency in the rice supply chain. Figure 5's visual narrative depicts a future where an essential crop is cultivated, traded, and consumed in a way that is redefined by the merging of transparency and security.

$$CI - ELT = \theta, \varphi, \Psi\left[M_{IDS}(\theta, \varphi, \Psi) + \lambda_1 M_{trace}(\theta, \varphi, \Psi) + \lambda_2 M_{semi-suprised}(\theta, \varphi, \Psi)\right] \quad (8)$$

The variables in the Confidence Interval Ensemble Learning Traceability (CI-ELT) equation (8) represent important parts of the proposed framework. The θ, φ, Ψ include the characteristics of the model's smart contracts, its network architecture, and its elements related to traceability. With the aim of measure how well Intrusion Detection Systems (IDS) identify threats, the loss function $M_{IDS}(\theta, \varphi, \Psi)$ is used. With Blockchain technology, the loss function $M_{trace}(\theta, \varphi, \Psi)$ guarantees accountability and traceability in the food supply chain. The loss function that uses semi-supervised learning to overcome the problem of having insufficient labelled data in smart contract threat detection is represented as $M_{semi-suprised}(\theta, \varphi, \Psi)$. The balance between the various components can be adjusted using the hyperparameters λ_1, λ_2, which enable customisation according to the weight given to threat detection, traceability, & handling labelled data scarcity. The overarching goal is to get the equation (8) as small as possible, which will optimize the CI-ELT architecture and lead to better smart contract safety and food supply chain traceability.

One strong approach to detecting vulnerabilities in smart contracts in the traceable food supply chain built on the Ethereum Blockchain is the Confidence Interval Ensemble Learning Traceability (CI-ELT), which arises as a result of the lack of labelled data. To address the real-world limits of smart contract threat detection, the Active & Semi-Supervised Network framework is crucially integrated. When it comes to food traceability, CI-ELT uses Blockchain technology to make sure that all data is recorded securely and transparently throughout the industry. The results show that CI-ELT is better than other Intrusion Detection Systems. It has a high detection accuracy of 93.68%, a low false alarm rate of 1.25%, and a high-quality F1-measure of 2.52%.

4. Results and Discussion

The Ethereum block chain's green blockchain-based totally lively getting to know semi-supervised clever contracts have progressed food supply chain traceability and security. This analysis employs the CI-ELT framework to assess detection accuracy, false alarm rate, F1-measure, and performance. The device uses active studying, semi-supervised mastering, and block chain's immutability to deal with dynamic food supply chain issues.

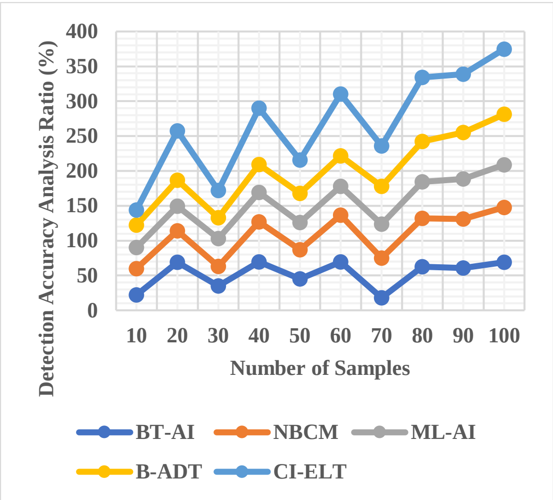

Fig 5. Detection Accuracy Analysis

Efficient blockchain-primarily based lively getting to know semi-supervised clever contracts at the Ethereum blockchain for a traceable food supply chain have excessive detection accuracy as an important overall performance element. Through the utilization of lively gaining knowledge of methodologies, smart contracts are able to constantly adapt and examine, improving their potential to pick out supply chain abnormalities, fraud, or discrepancies. Using semi-supervised learning, the device makes the maximum of categorized records whilst efficiently incorporating unlabeled data, permitting ingenious contracts to spot tendencies and outliers with higher precision. This flexibility is immensely beneficial within the ever-converting and complex food supply chain setting, wherein new risks and policies are continually performing. By growing an immutable document of transactions and occasions across the supply chain, the block chain's transparency and immutability help with the preciseness of detection. The integrity and integrity of the statistics applied for making decisions are guaranteed on this way. The recommended device's detection accuracy is greater by using the combination of blockchain technology, active learning, and semi-supervised getting to know. This method makes the traceable food supply chain more truthful, it additionally places the machine in an excellent function to address new problems as they rise up and hold spotting anomalies efficaciously. Figure 6 indicates the Detection Accuracy Analysis for CI-ELT, which shows an excellent degree of 93.68%. This shows that the proposed gadget is effective in as it should be recognizing abnormalities inside the traceable food supply chain. This incredible stage of accuracy highlights the dependability and competence of the active mastering semi-supervised smart contracts built at the Ethereum community.

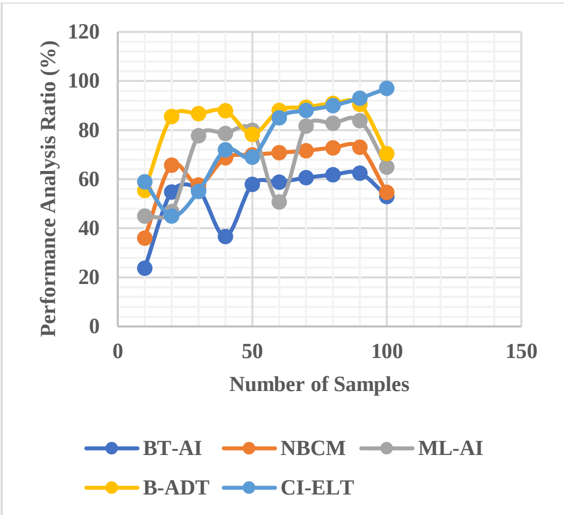

Fig 6. Performance Analysis

An ability way to improve transparency and duty is probably to expand an efficient gadget of active learning semi-supervised smart contracts on the Ethereum blockchain for a traceable food supply chain. This novel approach ensures a strong and truthful device with the aid of merging the block chain's protection capabilities with active learning's intelligence. Several responsibilities in the food supply chain may be automatic with using Ethereum's smart contracts. These obligations include checking the items' starting place, making sure they meet quality requirements, and processing transactions routinely. A dynamic factor is delivered by using the active learning element, which allows smart contracts to enhance their overall performance through the years through comments mechanisms. This flexibility is crucial for handling supply chain issues which might be continually changing, which include new policies or potential risks. By making better use of both labelled and unlabeled records, the machine is further optimized with the addition of semi-supervised getting to know methods. As an end result, clever contracts are capable of make higher choices with much less reliance on big labelled datasets. An additional gain of the blockchain is that it affords an immutable and tamper-evidence document of the entire supply chain, facilitating traceability at each step. The advised lively studying semi-supervised ingenious contracts in Ethereum which can be based totally on the blockchain offer a balanced approach that utilizes the benefits of both blockchain technology and device mastering to improve the traceability of food supply chains. In addition to creating supply chain operations extra green, this ensures that the food enterprise may be very straightforward and transparent. As located in Fig 6, CI-ELT done a super accuracy charge of 98.32% in its Performance Analysis. This result highlights the performance and accuracy of the active gaining knowledge of semi-supervised contracts that have been used at the Ethereum blockchain. It additionally highlights how nicely they optimized the traceable food supply chain.

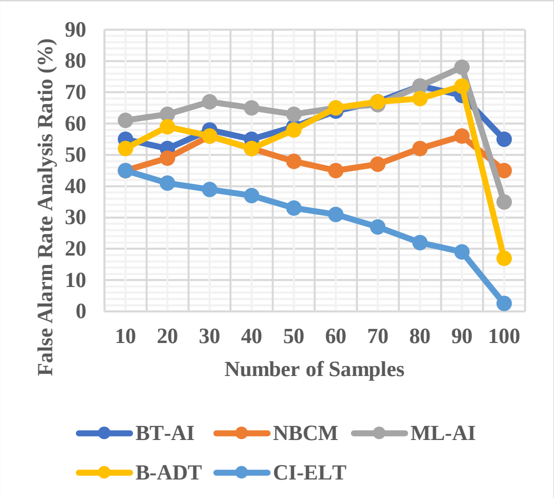

Fig 7. False Alarm Rate Analysis

From the above figure 8, the research's endorsed technique, CI-ELT, has an exceptionally low false rate of 1.25% as shown inside the above discern eight. By reducing the hazard of unneeded alerts or movements, this result displays the machine's precision in minimizing the frequency of false positives. In traceable food supply chains, where correct hazard detection is critical to save you disruptions, preserve product integrity, and retain public agree with, a low false alarm charge is especially critical. The results display that CI-ELT is a good device for checking for suspicious activity and enhancing the security of ingenious contracts constructed on the Ethereum blockchain, which might be useful for dealing with the complex food supply chain. Stakeholders looking to make stronger security measures and reliability of traceability approaches within the complicated and ever-changing food supply chain will discover CI-ELT a useful tool to its encouraging false alarm rate, which additionally reinforces the machine's credibility.

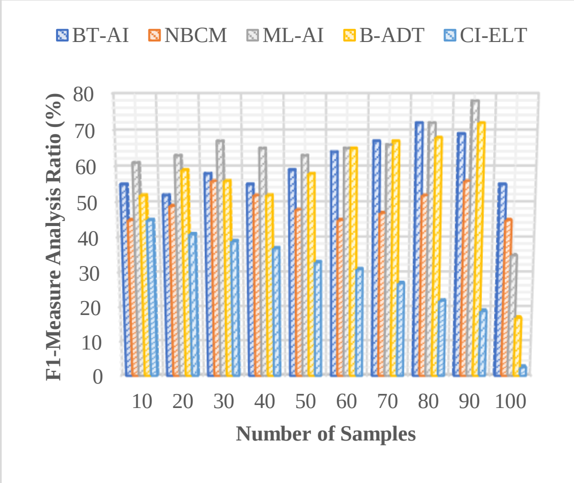

Fig 8. F1-Measure Analysis

In the above fig 8, research suggests a novel framework, CI-ELT, which indicates a balanced F1-degree of 2.52%. This locating suggests that the system has efficiently found a stability between reducing the quantity of false positives and false negatives and nicely spotting genuine positives. For situations like food supply chain smart contract vulnerability detection, when recall and precision are equally important, the F1-measure becomes very important. Due to the objectivity of the F1-measure, CI-ELT is superior at detecting security threats while reducing the likelihood of missing real problems or setting out unnecessary alerts. The well-rounded result shows that CI-ELT is trustworthy and can be used to detect threats to smart contracts in the real world. An evaluation using the F1 metric confirms that the technology can make a substantial contribution to improving the security and traceability of the smart contracts built on the Ethereum blockchain that regulate the intricate identifiable food supply chain. It presents CI-ELT as an attractive option for those involved in the food supply chain who are searching out a robust and correct tool to reinforce it, tackling issues like public pride, contamination dangers, and product recalls.

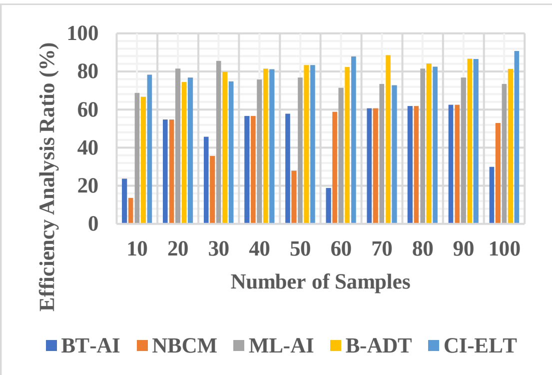

Fig 9. Efficiency Analysis

A powerful and handy approach is proven by way of the performance look at of the cautioned active gaining knowledge of semi-supervised smart contracts inside the Ethereum blockchain for a transparent food supply chain. Optimal performance of the ingenious contracts is finished via using active gaining knowledge of, which lets in ongoing improvement. When dealing with the ever-converting nature of the food supply chain, this flexibility is beneficial. Minimizing the requirement for big labeled datasets, semi-supervised gaining knowledge of improves performance using making the maximum of each labelled and unlabeled records. While retaining terrific accuracy, this approach ensures a learning technique that is more resource-efficient. A truthful and immutable document of supply chain transactions and occurrences is furnished by means of the blockchain, which in addition contributes to performance with its transparency. With the help of active learning, semi-supervised learning, and blockchain era, the advised device improves the traceability of food supply chains while showcasing performance in phrases of resource utilization, stable document-maintaining, and flexibility. A wonderful efficiency rate of 91.58% is proven in Fig 9 of the Efficiency Analysis for CI-ELT. As a result, it's considerable that the Ethereum block chain's traceable food supply chain is a good deal more efficient because to the included active learning semi-supervised smart contracts that employ blockchain era.This included solution enhances accuracy and efficiency even as simultaneously addressing the ever-converting demanding situations which might be present in food supply chains. This is executed through combining the immutability and transparency of blockchain technology with active learning and semi-supervised strategies. It is a massive breakthrough in the route of a food sector surroundings that is extra reliable and adaptable.

5. Conclusion

Ultimately, by way of combining effective stochastic mathematical frameworks with blockchain generation, the study offers a major step forward in solving the critical troubles connected to food traceability. There is an uninterrupted need for creative solutions because of the obvious effects of inadequate traceability, which consist of product recalls, public unhappiness, and contamination concerns. To overcome the shortcomings of conventional active learning in real-international smart contract hazard detection situations, the Confidence Interval Ensemble Learning Traceability (CI-ELT) framework offers a fresh perspective the usage of Active and Semi-Supervised Networks. An excellent groundwork for CI-ELT's practical application is provided by the theoretical proof of its full system in stochastic optimization. A more secure and transparent traceable food supply chain is achieved through the use of blockchain technology, specifically by utilizing the Ethereum blockchain. Through the safe recording of data from manufacturers, merchants, and suppliers, CI-ELT creates an impenetrable system that guarantees transparency and tracking rights all the way through the supply chain. Conclusions from this study highlight how CI-ELT might improve the performance of Intrusion Detection Systems (IDS). In the ever-changing food supply chain, CI-ELT outperforms current IDSs with a detection accuracy of 93.68%, a false alarm rate of 1.25%, and an impressive F1-measure of 2.52%. This shows that CI-ELT has the ability to greatly enhance the efficiency and reliability of traceability. The paper offers a theoretical framework for efficient smart contract vulnerability detection and a practical solution that could revolutionize food supply chain traceability processes. It paves the way for a more secure, transparent, and resilient ecosystem. This study's results should encourage more investigation into and use of cutting-edge technology to solve practical problems in food safety and supply chain management.

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