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Blockchain-Based Intelligent Inventory Management for Hospital Supply Chain (HSC) with Deep Learning Techniques

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Abstract:

A medication shortage may have far-reaching consequences, making it an important inventory management concern for healthcare organizations. Intelligent demand forecasting is essential to make cold chain businesses more competitive and save transportation and storage costs. Hence, this paper proposes a blockchain-based intelligent inventory management model (BC-IIMM) with deep learning techniques for hospitals to prevent running out of supplies, run their systems sustainably, and optimize their profits in the hospital supply chain (HSC).Preventing the contamination of pharmaceuticals requires a pharmaceutical cold chain monitoring system that uses IoT devices, blockchain, and cloud computing to track items across their entire supply chain reliably. One other perk is that both doctors and patients may benefit from drug recommendations made by a deep belief network (DBN) model. Further, to construct deep learning (DL), the proposed cold chain monitoring system produces large-scale, high-quality data. Holding cold chain items would become less expensive and cold chain inventory management decisions would be easier with it.Next, they provide a numerical result proving the suggested method works better than the baselines regarding refilling cost and shortage rate.

Keywords: Deep Learning, Blockchain, Cold Chain, Supply Chain Management, Hospital Supply Chain (HSC).

1. INTRODUCTION

The pharmaceutical cold chain is an important part of the logistics business [1]. It is a well-organized enterprise that involves the manufacturer and the consumer of chilled medication for disease treatment, diagnosis, and prevention [21]. Manufacturing, shipping, warehousing, and consumption are all part of the pharmaceutical cold chain [3]. Pharmaceutical cold chains transport various perishable medical supplies, including diagnostic, therapeutic, and preventative biological materials [22]. Representative biological products include vaccinations, antisera, toxoids, immunological preparations diagnostic reagents, and antibodies [5].Pharmaceutical cold chain management is being impacted by unprecedented opportunities and risks [23]. Technological and medical advancements are fueling the refrigerated pharmaceutical product sector, which in turn is expanding the pharmaceutical cold chain [7]. Because of the special characteristics of refrigerated medical commodities, the pharmaceutical cold chain requires very stringent shipping and storage regulations [17] [24]. Physical processes are relied upon by the cold chain to maintain stable temperatures across the supply chain [9]. Attaining the target temperature control requires dedicated refrigeration machinery, loading docks, and storage facilities [25]. Globally, the pharmaceutical cold chain industry is only getting its feet wet now [28] [11]. Most problems with pharmaceutical quality stem from cold chain logistics, and the risk of cold chain breaches is a constant worry [26].

Since Blockchain (BC) monitors legitimate narcotics and stops the distribution of counterfeit ones, researchers think it may provide the technological foundation for such systems [13]. Medications that "are manufactured fraudulently, mislabelled of low quality, hiding the source details or identity, and the defined standard" are considered counterfeit, according to the World Health Organization (WHO). Blockchain technology (BCT) helps the healthcare industry become more standardized and reaps several advantages [6] [16][27]. The original intention behind creating BC was to use it as Bitcoin's transaction log. It provides a distributed ledger system for keeping records of data organized into different "blocks" [8] [14] [15]

The paper's novelty is: Specifically for the pharmaceutical industry, this research creates a (BC-IIMM). Continuous monitoring and tracking of the medication supply is the primary emphasis of the suggested BC-IIMM method for combating forging issues. Two main components make up the BC-IIMM method: a DL-based customer recommendation system and BC-enabled DSC administration. The goal of developing deep learning was to reduce the storage cost of cold chain products by aiding decision-making in cold chain inventory management [10]. In addition, a DBN model is used by the medical industry to suggest the most effective or highly regarded drugs to clients.

2. LITERATURE STUDY

To address this, an evolutionary fuzzy method based on multiple-criteria decision-making (MCDM) is used [18]. According to the experimental data, the proposed solution shortens the makespan and increases customer preference compliance by 29% [12]. A hybrid fuzzy DEMATEL and best-worst method (FDEMATEL-BMW) framework is used to test supply chain resilient capacities (SCRCs), and the vulnerabilities are categorized into cause-and-effect vulnerabilities [19]. The objective relevance of the validated issues was determined, and the performance of five pharmaceutical firms in dealing with these hurdles in LARG SC adoption was evaluated using the novel MEREC-TOPSIS approach under spherical fuzzy sets [20].The findings revealed 35 verified obstacles to implementing LARG SC, including 10 green, nine agile, and seven lean issues.The Secure Drug Supply Chain Management Framework (SDSCMF) can use machine learning algorithms to achieve higher security and intelligence levels [2] [21]. To enhance the intelligence and security of blockchain-based DSCM, the suggested architecture employs attack detection modules based on machine learning and Bidirectional Encoder Representations from Transformers (BERT) [4].

3. PROPOSED METHODOLOGY

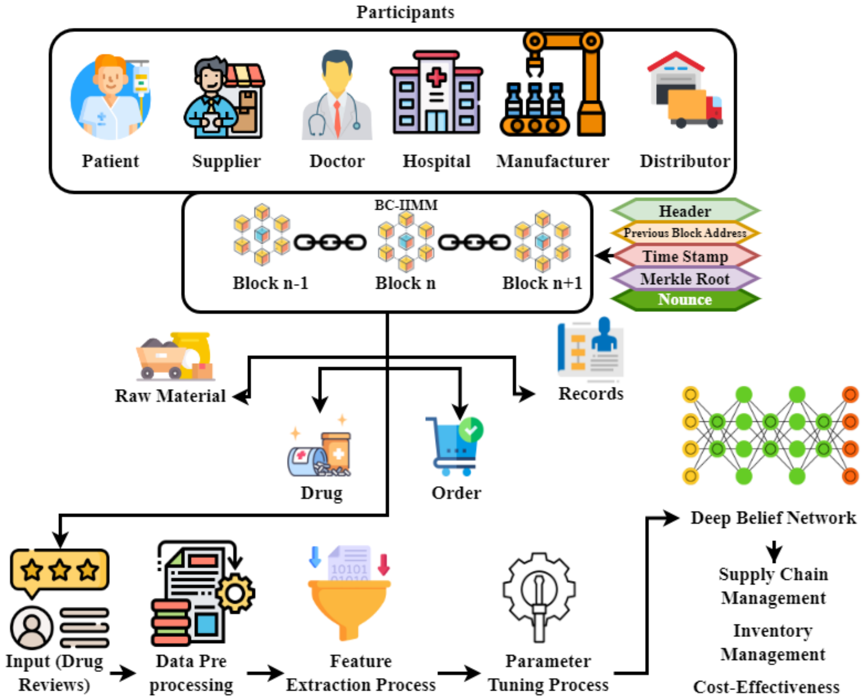

Figure 1: Proposed BC-IIMM

BC-IIMM was introduced for automatic DSC management and recommendation in smart pharmaceuticals in this research. To combat forging, BC-IIMM proposes continuous medication supply monitoring and tracking. The BC-IIMM scheme focuses on DL-based customer recommendation and BC-enabled DSC management. Figure 1 depicts the whole BC-IIMM procedure. The world state dataset component recovered user applications or needs and recorded ledger states well. Thus, it automatically records the current status, which the function's developer may check without reviewing the transaction log. The global state dataset might store the key-value pair. The database instantaneously updates the state value after a transaction or change. Both Level DB and Couch DB are good options. The default state database at the main choice level contains all network nodes that store smart contract data as a key-value pair. Couch DB queries reveal actual data.

Additionally, it simplifies REST API data access for searches. Couch DB can store our network's data as indicated due to these qualities. BC, the second portion, tracks the transaction log steps needed to update the world state database. The blocks mechanism then saves and links this transaction to a chain. The BC network records transactions chronologically.

There is no way to erase or alter BC data because of its immutability. A drug review dataset that has been pre-processed to remove noise is available for use before any suggestions have been made. Feature extraction follows using the TF-IDF model. Assessing the mathematical consequences of document words is made possible by statisticians using TF-IDF. To some extent, vectorisation is similar to One Hot Encoding. With a TF-IDF value instead of 1, the word value is represented. Put, the TF-IDF value is the sum of the TF and IDF dimensions. Based on the DBN paradigm, this article suggests medication options. The HL and VL parameters of a restricted Boltzmann machine (RBM) are known. Equation (1) indicates that the VL is in charge of input, while the HL is responsible for learning higher-level semantic characteristics from the dataset.

$$F(u,g,\theta) = -\sum_n a_n u_n - \sum_n a_n g_n - \sum_{ng} z_{nm} u_n g_n \tag{1}$$

Equation (1) represents the RBM variable $\theta = (z_{nm}, b_n, a_m)$with z_{nm} representing weight between hidden $g_n$and visible unitsu_n, and a_m and b_n defining bias vectors. Computation of u and g joint likelihood distribution calculated in equation (2):

$$Q(u,g,\theta) = \frac{1}{W(\theta)} f^{-F(u,g,\theta)} \tag{2}$$

Where $W(\theta) = \sum_u \sum_g F(u,g,\theta)$ represents the normalization factor in equation (2). Where$u$ and g probability functions are below expressed in equation (3a-b):

$$Q(g_n = 1|U) = H(\sum_{n=1} z_{nm} u_n + b_m) \tag{3a}$$

$$Q(g_n = 1|U) = H(\sum_{n=1} z_{nm} g_n + a_m) \tag{3b}$$

The logistic function is denoted by $h(y) = 1/(1 + exp(y))$, where m is a characteristic of the network's dimensions.Using iteration, the RBM mechanism may be trained, and the following GD approach achieves the variable$\theta = (z_{nm}, b_n, a_m)$ described in equation (4).

$$\theta = \theta + \varepsilon \times \frac{\partial In[\prod_{n=1}^{l} q(V|\theta)]}{\partial \theta} \tag{4}$$

The learning rate is represented by ε in Eq. (4). The estimated expectation of the training dataset is denoted by $(.)_{data}$ in Eq. (5), whereas the expectation of the reconstruction model is denoted by $(.)_{rec}$. The following is the improved condition for determining DBN's weight and bias discussed in equation (5):

$$\Delta z_{nm} = \varepsilon((U_n g_m)_{data} - (U_n g_m)_{rec})$$

$$\Delta b_n = \varepsilon((U_n)_{data} - (U_n)_{rec})$$

$$\Delta a_n = \varepsilon((g_n)_{data} - (g_n)_{rec}) \tag{5}$$

The next step in avoiding the local optimum solution is fine-tuning the RBM variables. Regarding data extraction, RBM shines because of its superior feature learning power. However, when applied to complicated non-linear data, the RBM efficiency of feature extraction is limited. Because of this, the DBN investigates a highly hierarchical representation of the training set. A single RBM is considered to be both adjacent DBN layers.

4. NUMERICAL RESULTS AND DISCUSSION

A novel BC-IIMM approach for smart pharmaceutical industry automated DSC management and suggestion procedures was presented in this research. Central to the BC-IIMM strategy for overcoming forging challenges is the continual measurement and monitoring of the drug supply. The BC-IIMM approach uses a DSC management system that BC enables and a customer recommendation system based on DL.The pharmaceutical industry also makes use of a DBN model to advise customers on the best drugs to take. The BC-IIMM approach seems to be effective in terms of simulations. This study uses the public Kaggle dataset for warehouse inventory and drug supply chain management [22].

i) Drug Supply Chain Management Ratio (%)

The suggested system uses blockchain, cloud storage, and IoT to control drug supply chains. This would protect and track pharmaceuticals throughout their lives. Monitoring prevents important pharmaceuticals from falling into the wrong hands, improves transparency, and reduces errors. The hybrid Deep Belief Network (DBN) model that offers the best pharmaceuticals to healthcare practitioners and consumers enhances clinical and consumer decision-making.

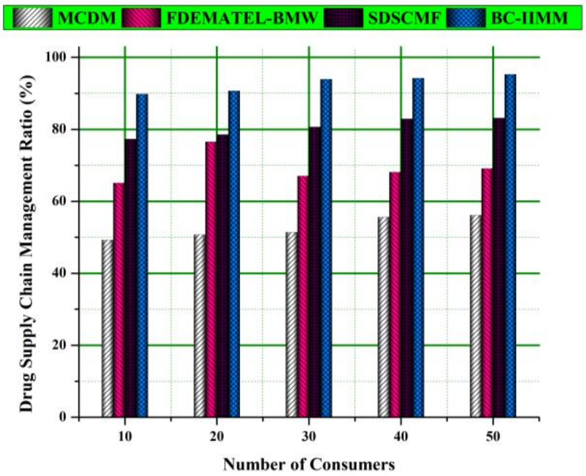

Figure 2:Drug Supply Chain Management Ratio (%)

The model analyzes huge cold chain monitoring system data using deep learning. Intelligent demand forecasting is conceivable. Forecasting decreases prescription shortages, optimizes inventory, and lowers storage expenses. Supply chain efficiency improves hospital sustainability and profitability using the BC-IIMM. Reduce replenishing costs and scarcity. The pharmaceutical cold chain management strategy is effective, transparent, and robust after all considerations.

ii) Inventory Management Ratio (%)

The approach uses BC-IIMM and deep learning to optimize the hospital supply chain via inventory management. Blockchain technology can track and secure medicinal items throughout their lifespan. This protects them against human mistakes, manipulation, and delays. The system also uses IoT sensor data in the cloud to assess real-time demand, product health, and inventory levels.

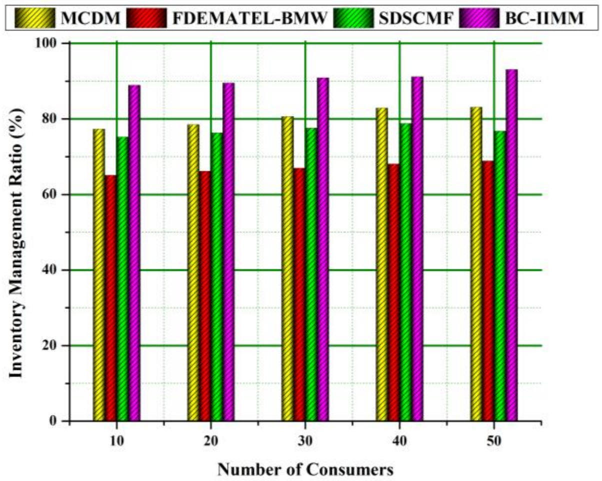

Figure 3: Inventory Management Ratio (%)

Figure examines the inventory management ratio (%). To improve the system, a hybrid Deep Belief Network (DBN) model might estimate the demand and supply of highly rated or best-matched pharmaceuticals. This would reduce overstocking and shortages. Healthcare organizations may optimize inventory levels and cut cold chain product storage expenses by employing deep learning algorithms to analyze this data and make smart decisions. This increases supply reliability, lowers costs, and makes the system more sustainable. More effective, transparent, and straightforward hospital inventory management is the result.

5. CONCLUSION

This article examines the Cost and safety aspects of pharmaceutical cold chain management. Blockchain technology is used for trustworthy product tracking to ensure that pharmaceutical things are secure and reliable. The data storage problem may be resolved by integrating a cloud storage module into the pharmaceutical cold chain monitoring process using blockchain technology. Better pharmaceutical item demand forecasting and inventory management may be achieved by applying deep learning algorithms to the temporal and geographical features of pharmaceutical cold chain data kept in the cloud and on the blockchain. Using a hybrid metaheuristic algorithm in the future may enhance the performance of the suggested model. Another benefit is that the suggested model's output may be tested on a massive real-time database.

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