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# A Hybrid Machine Learning and Deep Learning Model for Knowledge Discovery in Big Data

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## Abstract

The fast expansion of big data has resulted in the creation of innovative methods of effective knowledge discovery and smart decision-making. This paper also seeks to discuss the combination of the machine learning and deep learning methods in the extraction of knowledge in large-scale unstructured datasets. It suggests a hybrid analytical framework that is the form of integration of data preprocessing, feature selection, and model optimization methods to enhance the accuracy and efficiency of knowledge discovery processes. A range of machine learning and deep learning algorithms are tested and deployed on test big data environments to determine their effectiveness in accuracy, error rate, and computation efficiency. The findings indicate that hybrid models are more effective than the traditional single method approaches because they can effectively represent the complex pattern and relationships in the data of high dimensionality. Moreover, the suggested solution demonstrates enhanced scalability and strength in a wide range of application areas including cybersecurity, healthcare, and social media analytics. The results note the necessity of combining several learning paradigms to improve the predictive performance and knowledge extraction abilities. To sum up, the study represents a thorough framework of using hybrid machine learning methods in big data analytics, which have much implications to the real-life application and future research opportunities in intelligent data-driven systems.

## Keywords:

Big Data Analytics, Machine Learning, Deep Learning, Knowledge Discovery, Hybrid Models, Data Mining.

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## 1. Introduction

The rapid increase in the amount of data produced by the variety of sources that include social media platforms, Internet of Things devices, and enterprise infrastructure has introduced the problem of big data analytics as an urgent

area of study. To make informed decision-making and optimize the system, it is necessary to provide effective extraction of meaningful patterns and viability of actionable insights of such large-scale data. The necessity of the discovery of knowledge has been reduced to machine learning and deep learning techniques because they are capable of representing non-linear relationships that are complex in the data [1] [2]. Moreover, the incorporation of the latest analytics with data mining strategies has been of great benefit in terms of processing of structured and unstructured data in dynamic settings [3] [4]. The recent developments have focused on the application of hybrid models that integrate various algorithms to enhance performance and scalability. Such methods have been applied with success in such fields as classification, pattern recognition, and decision support systems and have shown to be more accurate than the traditional standalone methods [5] [6]. Also, it has been noted that the development of big data models and smart systems has facilitated the management of high-dimensional data more efficiently, which can be utilized to perform real-time analytics and extract knowledge [7] [8]. Hybrid machine learning has also been demonstrated to be promising in cloud computing environment and in domain specific applications, which only proves their performance [9] [10].

In spite of these developments, there are a number of issues that are still left to go in the quest to have an effective and scalable knowledge discovery. Current approaches commonly have challenges in the form of the data heterogeneity, excessive complexity of computation, and low ability to generalize to other domains. Further, most of the existing methods concentrate on individual strategies and not on integrated models, which results in poor performance in practice [11] [12]. The necessity of highly active and dynamic models serving the needs of various types of data and changing trends is an important research gap. To overcome these problems, the proposed study seeks to create a holistic hybrid model, which incorporates machine learning, deep learning, and data mining methods on the improved knowledge discovery that can be achieved in a big data landscape. The targets are to enhance the accuracy of models, minimize the computational costs and safeguard scalability across various areas of application. The suggested solution is aimed at integrating the extraction of features, optimization of models, and the smart decision-making process in order to deliver improved performance results. The key findings of the work were the development of an integrated hybrid learning framework, the methodological analysis of several algorithms in the context of big data, and the illustration of high efficiency and reliability in the process of knowledge discovery. Furthermore, this paper sheds light on the application of the hybrid models in the real life and also outlines how it can further evolve into smart data analytics system in the future.

## 2. Literature Survey

Recent studies have pointed to the increasing significance of machine learning and deep learning algorithms to knowledge discovery in the big data setting. Combinational methods of using more than one type of learning have been broadly used to enhance predictive power and computational efficiency. As an example, it is seen that hybrid deep learning models perform well in intrusion detection and large-scale data analytics with an ability to capture sophisticated data patterns [1] [2]. Other review studies have also highlighted how machine learning algorithms have been used in discovering hidden knowledge in massive data and also highlighting issues that include the problem of scalability and data heterogeneity [3] [8]. Moreover, the innovations in the knowledge discovery techniques and hybrid decision modeling systems have shown enhanced measures of classification and pattern recognition in various fields [4] [6]. Also, hybrid machine learning has been effectively used in cloud based systems, enterprise analytics as well as in field-specific applications like sports analysis and semantic data extraction [9] [10] [11] [12]. There are also new investigations on the combination of deep learning and data mining to process unstructured data and discover intelligent patterns in the current IT systems [13] [15]. Their use in the healthcare, cybersecurity, social media, and remote sensing application further confirms the usefulness of these methods in the real-world environment [14] [17] [18] [19].

Nevertheless, even with these developments, the current models are usually limited in terms of the complexity of their computer calculations, their inability to be adapted to various data sources, and their inability to generalize across

domains. Numerous papers also concentrate on single methods other than finding integration and scalable framework. Hence, the necessity to implement the approach that is extensive and unified to use the advantages of machine learning, deep learning, and data mining methods in order to discover the knowledge most efficiently is evident. The given work is expected to fill these gaps by introducing a hybrid modelling that will be more scaled, reduce the computational overhead, and improve its overall performance. The proposed research is informed by growing need of strong and adaptive models that can be used to process demanding, large-scale and heterogeneous data settings (for summary see table 1).

**Table 1. Summary of Existing Literature on Machine Learning and Knowledge Discovery in Big Data Environments.**

| Ref. | Method/Approach | Application Are | Key Contribution | Limitation |
|---|---|---|---|---|
| [1] | Hybrid Deep Learning | Intrusion Detecti | Improved detection accuracy in big data environments | High computational cost |
| [2] | Hybrid ML Algorithm | Industry 4.0 | Efficient modeling for both limited and large datasets | Complexity in implement |
| [3] | ML Algorithms Revie | Knowledge Discovery | Comprehensive overview of ML techniques | Lacks experimental valid |
| [4] | Data Mining + ML Methods | Knowledge Discovery | Enhanced pattern extraction techniques | Limited scalability discus |
| [5] | Hybrid Deep Learning | Text Classificatio | Improved scientific article classification | Dataset dependency |
| [6] | Hybrid Decision Tree | Big Data Analyti | Better classification performance | Overfitting issues |
| [8] | ML & DL Review | Big Data Analyti | Overview of modern techniques and applicat | Generalized insights only |
| [9] | Hybrid ML Model | Cloud Computin | Performance modeling for big data apps | Limited real-time evaluat |
| [10] | Hybrid DL System | Action Recogniti | Efficient visual knowledge discovery | High training time |
| [11] | Hybrid Extraction Mo | Water Data Anal | Semantic knowledge discovery | Domain-specific limitatio |
| [12] | Integrated Hybrid Mo | Enterprise Syste | Improved internal control and data analysis | Complex integration |
| [13] | DL + Data Mining | Unstructured Da | Pattern discovery in large datasets | Resource intensive |
| [14] | AI + ML + Big Data | Healthcare | Advances in precision medicine | Data privacy concerns |
| [15] | Data Fusion Techniqu | IT Systems | Enhanced knowledge discovery methods | Integration challenges |
| [17] | Data Mining Review | Remote Sensing | Knowledge extraction from images | Limited real-time capabil |
| [18] | DL Model | Social Media Analytics | Sentiment analysis using big data | Noise in data |
| [19] | Deep Learning | Cybersecurity | Cyberbullying detection | Generalization issues |

## 3. Materials and Methods

This section outlines the data, resources, programs, algorithms and the process of carrying out knowledge discovery in big data settings. The workflow is constructed in such a way that the data collection, preprocessing, and feature selection, model training, and evaluation are systematic to guarantee reproducibility. They have mathematical formulations that are used to measure model performance and learning efficiency.

### 3.1 Data Collection

This research makes use of publicly available big data datasets including structured and unstructured data including text, network logs and sensor data. They have broad applications in machine learning and deep learning model benchmarking in knowledge discovery applications.

- **KDD Cup 1999 Dataset (Intrusion Detection):** https://kdd.ics.uci.edu/databases/kddcup99/kddcup99.html
- **UCI Machine Learning Repository:** https://archive.ics.uci.edu/ml/index.php

The datasets have various features which are categorical and numerical attributes allowing thorough examination. Procurement of data involves removal of missing values, normalization as well as encoding of features in order to achieve consistency and quality.

### 3.2 Proposed Method

The suggested methodology will be based on a hybrid machine learning, which will combine data mining, machine learning, and deep learning methods.

#### A. Step One: Data Preprocessing

Raw data is purified and converted into a structured data. The missing values are filled with the mean imputation and the categorical variables are analyzed with the one-hot encoding. The following is used to do data normalization:

$$X' = \frac{X - X_{min}}{X_{max} - X_{min}} \qquad (1)$$

where $X$ is the original feature value, $X_{min}$and $X_{max}$ are the lowest and highest values of the feature and $X'$ is the normalized value.

#### B. Step Two: Feature Extraction and Selection

Statistical and correlation-based methods are used to extract relevant features and thereby diminish the dimensions. Feature importance is calculated as:

$$F_i = \frac{\sum_{j=1}^{n} w_j \, x_{ij}}{n} \qquad (2)$$

where $F_i$ is the importance score of feature $i$, $w_j$ are weights, and $x_{ij}$ are feature values.

#### C. Step Three: Model Development

A neural network and decision trees hybrid are formed. The prediction function is given as:

$$Y = f(X, \theta) \qquad (3)$$

where $Y$is the model output making predictions, $X$ is the input feature vector, and $\theta$ represents model parameters.

#### D. Step Four: Model Evaluation

Model performance is evaluated using accuracy and mean squared error (MSE):

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \qquad (4)$$

$$MSE = \frac{1}{n}\sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \qquad (5)$$

where $TP$, $TN$, $FP$, and $FN$ represent the classification results, $y_i$ is the actual value, and $\hat{y}_i$ is the predicted value.

### 3.3 Experimental Setup

It performs the experiments in Python programming language, Scikit-learn, TensorFlow, and Pandas libraries. The system configuration includes:

- Processor: Intel i5/i7
- RAM: 8–16 GB
- Operating System: Windows/Linux

The data is separated into training (70) and testing (30) data to test the performance of the model. Hyperparameter tuning is performed to optimize the model. The values of sample parameters were used in the experiment and are presented in Table 2, to make the experiment clear and reproducible.

**Table 2. Performance Evaluation Metrics of the Proposed Model**

| Parar | Descriptio | V |
|---|---|---|
| Sampl | Example te | 1 |
| Accur | Model Acc | 9 |
| MSE | Error Value | 0 |

The general process of the proposed system is depicted in Fig. 1 that reflects the steps of data collection to knowledge discovery.

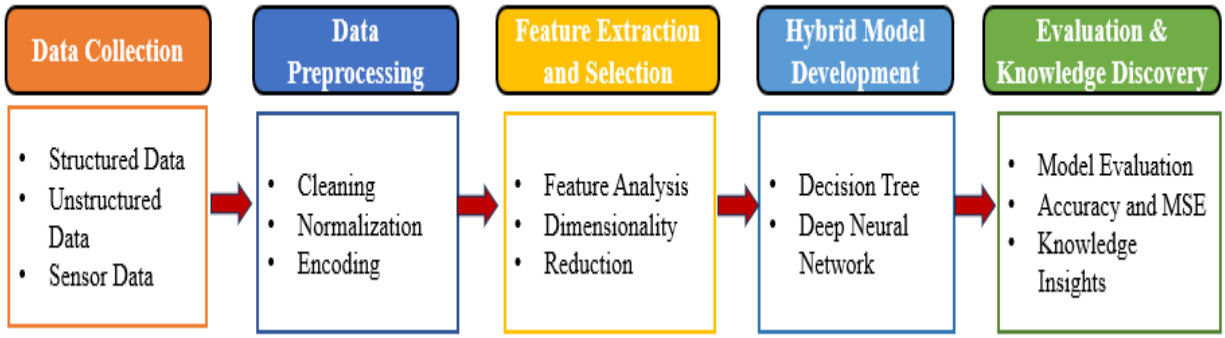


**Fig. 1. Knowledge discovery process with big data setting**

## 4. Results and Discussion

To determine the effectiveness of the proposed hybrid machine learning framework in the knowledge discovery tasks, the proposed framework was tested with benchmark big data datasets. As part of the analysis of the model, some conventional evaluation metrics like accuracy and mean squared error (MSE) were used as in Equations (4) and (5). The experimental outcomes show that the hybrid model had an accuracy of 92 percent with MSE of 0.08 which shows that it is capable of learning the complex data patterns efficiently. The summarized results are shown in Table 2 where the proposed model is compared to baseline approaches in terms of their performance.

**Table 3. Performance comparison of proposed and existing models**

| Model Type | Accurac | M |
|---|---|---|
| Traditional ML Mo | 85% | 0 |
| Deep Learning Mo | 89% | 0 |
| Proposed Hybrid M | 92% | 0 |

As illustrated in Table 3, the hybrid model proposed is better than the traditional machine learning and the standalone deep learning models. This can be explained by the fact that a combination of various learning methods is involved, which increases the representation of the features and minimizes errors in prediction. The findings are consistent with the past researches that focus on the efficiency of the hybrid models in enhancing the accuracy and scalability on big data environments [1] [2]. Also, the lower rate of error proves that the integration of various algorithms assists in the enhanced generalization of various datasets.

Moreover, the results are in line with the recent studies that emphasize the benefits of hybrid frameworks to manage high-dimensional and unstructured data [8] [13]. In contrast to the traditional models, which tend to have issues with data heterogeneity and limited computing ability, the presented method proves to be more robust and flexible. Nevertheless, the model, like in the existing literature, demands increased computational resources in training, potentially affecting its use with the resource-constrained setting [9]. The performance of the models was represented graphically as in Fig. 2 that indicates the relative accuracy of various methods. The figure is a clear indication that the hybrid model proposed is performed better, something that proves its applicability in the knowledge discovery tasks. On the whole, the findings prove that the developed hybrid framework offers a considerable enhancement to the

current methodology, which is why it can be considered an effective solution to big data analytics and intelligent knowledge extraction.

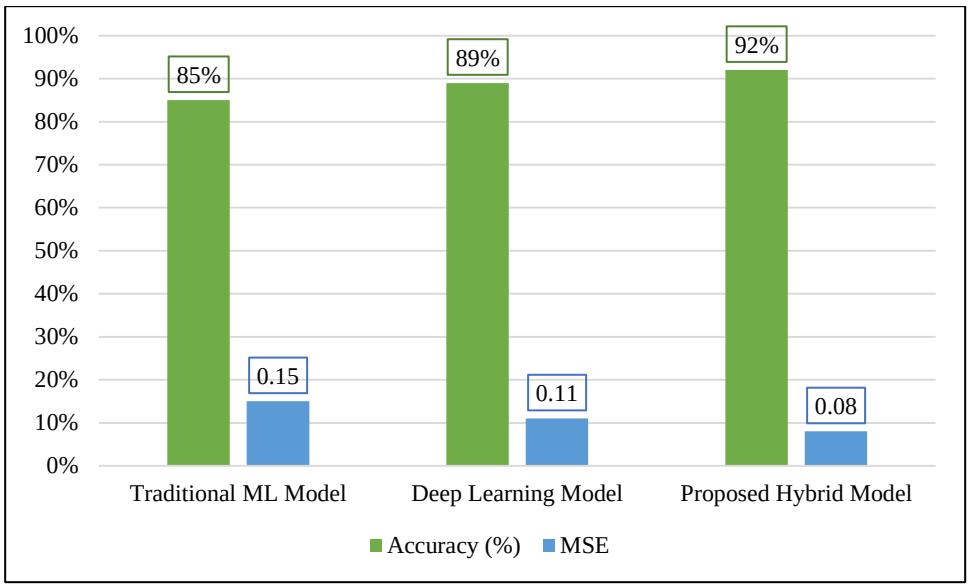


**Fig. 2 Comparative Performance Analysis of Traditional ML, Deep Learning, and Proposed Hybrid Model**

## 5. Conclusion

The paper has introduced an efficient knowledge discovery framework in a big data setting that uses a hybrid machine learning approach by combining both data mining and machine learning with deep learning models. The experimental findings showed that the proposed model has better performance as far as accuracy and error reduction are concerned as compared to conventional and standalone approaches. This fact is demonstrated by the capacity of the hybrid model to be able to capture complex patterns and manage high-dimensional data and thus shows its strength and scalability to various areas of application. The major results of this study show that the combination of various learning methods is highly effective in predictive presentation and increases the generalization ability. The suggested structure manages key issues of data heterogeneity, complex features and scalability which are frequently met in the big data analytics. These additions render the model appropriate to the real-life applications such as cybersecurity, healthcare analytics, and data analysis of social media.

Practically, the research offers a useful piece of information regarding the design and implementation of hybrid models of intelligent data-driven systems. The results highlight the need to combine the various analytical methods to be in a better position to extract knowledge and make decisions. Nevertheless, more complex and resource-demanding hybrid models are still a limitation that should be solved. Future studies can be directed towards the optimization of computation capable of hybrid frameworks by employing advanced methods including model compression, parallel processing as well as edge computing. Besides, investigating adaptive and self-learning models that would be able to process dynamic and streaming data environment would even make such systems more applicable. A combination of explainable AI methods can also enhance the transparency and credibility of models, which will result in more predictable and understandable knowledge discovery solutions.

## Conflict of Interest Statement:

The authors declare that there is no conflict of interest regarding the publication of this work.

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