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Crime Prediction Using Advanced Deep Learning Techniques: A Systematic Review

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ABSTRACT

Over the last couple of decades, researchers have searched for patterns in the occurrence of crimes to predict crimes using intelligent methods based on Deep Learning accurately. To find out the variety of Deep Learning algorithms applied to the tasks of anticipating crime, this current review paper analyzes more than 150 studies. Researchers are given access to datasets that they use to predict crime; the paper discusses the techniques often implemented in algorithms as well as various patterns and components related to criminality that employ Deep Learning. The review also outlines strategies and potential challenges that must be addressed to improve the efficiency of crime prediction. To finish, the detailed literature review on the application of Deep Learning for crime prediction presented in this paper should be useful to scholars interested in this field. Crime estimation strategies can be raised among authorities to deter and prevent criminal actions even more effectively.

Keywords: Deep Learning, crime prediction, crime detection, crime datasets.

1. INTRODUCTION

It is undoubtedly difficult to fix the gaps in the current crime detection system, as it is a complex topic requiring advanced methodologies. Due to the increase in crime cases and advancements in technology, academia has been presented with an excellent opportunity to analyze crime detection using low-level features through Deep Learning algorithms [1]. The recent literature focuses on the development of Deep Learning techniques for crime detection and explains how some of these modern tools are used to detect crime, outlaws, and trends in criminality, and prevent criminal activities. For accurate crime rate prediction in specific cities, these computer programs are trained on corruption data that possess either a temporal or spatial component. For example, criminal data, with time, place, and the kind of episodes of corruption, has been dealt with by Deep Learning models. This data is then used for the creation of other forecasting models that can identify probable locations of crime and potential future events in crime episodes. They also use Deep Learning in predicting crimes in Artificial Intelligence and Video analysis [2]. From surveillance cameras, the technique has been used to analyze the video data and recognize and characterize criminal incidences of aggression, theft, and mischief. Identical machines also integrate drones and other forms of aerial equipment with highly advanced Deep Learning methods to provide new opportunities for monitoring and preventing legality violations. These processes have also been used in analyzing corruption data which is gathered from police records, social media, and crime reports among others. Deep Learning algorithms exhibit an important tool in fighting criminals through automating this process hence increasing the possibility of detecting and combating crimes as they occur.

Despite the benefits of using Deep learning for crime prediction, there are several effective barriers to realizing the benefits. But there are several challenges and foremost is the question of crime statistics and data quality. Most of the time, the crime data we encounter is somehow incomplete or inconsistent, or a mixture of both, which makes it extremely challenging to train good models. Third, mere historical data could contain some form of prejudices that could amplify injustice in modeling. There are also ethical and privacy concerns when collecting personal data for research because it is a violation of a person's rights. It is necessary to resolve these problems to provide realistic and fair Deep Learning for crime prediction.

The increasing complexity of Deep Learning models poses additional challenges in interpretation. However, the practical application of these models may have severe restrictions because of their complexity and ambiguity in understanding and interpreting. Making models understandable, or having the ability to explain why certain predictions are given is crucial when it comes to applying these techniques to the crime prediction problem. Additionally, recent advances in Deep Learning approaches for crime prediction offer significant potential in talking this composite problematic. Still, there are still many barriers to address and many of the tasks to achieve already such

technologies can extend their potentiality to the full. This work provides a preliminary idea of the use of Deep Learning in crime prediction and a review of the works on the topic. The research article enhances understanding of Deep Learning's role in crime prediction and contributes to the academic community by highlighting its potential and the challenges that must be addressed [3].

Therefore, this work's main contributions are the following: first, it expands the body of literature by combining previous research It identifies local crime utilizing cutting-edge Deep Learning techniques. The second limitation is the restricted number of potential datasets that are available is removed in this article. To preserve the information resources for future researchers, we have emphasized particular openly obtainable statistics connected to area crime forecasting that have been used in earlier research. Thirdly, this work logically presents further research questions and outlines potential areas for the research community to explore of study to close the current research gaps in neighborhood crimes.

2. METHODOLOGY

We manually reviewed and filtered the works after applying automated techniques. Each piece was carefully examined to finalize the selection. We concentrated on key components for selection, including the article's goal or topic, the authors' datasets, and accuracy rates. This survey aims to highlight datasets that academics can use to develop cutting-edge algorithms and generate meaningful results in their research.

The primary focus of this study is to identify and categorize effective algorithms for forecasting local crimes. In our early study, we analyzed and predicted crime patterns in New York City using statistical methods. Our previous paper received considerable attention, prompting us to further investigate effective strategies in this field. To choose the research articles for this review, we used a methodical process.

For this study, we looked at publications about crime prediction from a variety of databases. For datasets like IEEE and ACM, we used wildcard characters to include all potential variations of key terms in our search, making sure that our search encompassed variations of important terms. The primary goal of this research is to examine previous studies on crime prediction. Furthermore, we aim to support the investigate public by sharing datasets used for algorithm applications. We applied several restrictions to our keyword searches to eliminate studies that were not relevant [4]. There have been many datasets cast-off in crime detection and forecast examine articles. Various datasets have been utilized by recent researches [5] like the Chicago Crime Dataset, NYC Crime Dataset, LA Crime Dataset, and global datasets.

Figure 1. shows the trend of the research publications in the period of 2020 to 2024. The horizontal bar shows the number of years where the research was published, while the vertical bar shows the counting of articles. The publications also climbed up, moderating at about 120 in 2020 and rising to nearly 200 in 2024.

This trend indicates that a clear upward shift continues to take place through the years perhaps due to the growing

development of academic disciplines and more importance being placed on research publication.

Based on their uniqueness and significance, we chose 30 articles for the main text, while the remaining 20 were included in an appendix. This survey utilized both automatic and manual searches. Initially, we concentrated on digital searches that were automated. To choose a collection of articles pertinent to our study goals, we conducted a manual examination of the papers in the last stage.

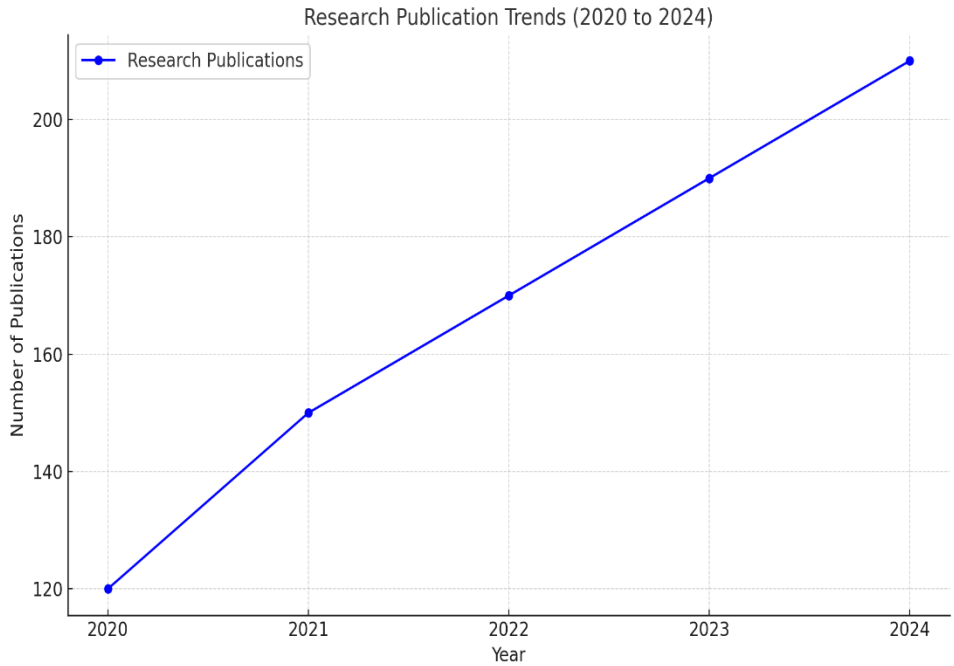

Figure 1: Publication trend of crime from 2020 to 2024

3. CRIME DETECTION FRAMEWORK

Figure 2. provides a framework overview of performing crime analysis based on data analysis techniques. Thereafter comes data collection, where relevant information is sourced. This is succeeded by preprocessing, a data refinement step, to ensure the data to be analyzed is of good quality. The following step is attribute selection where the analyst selects relevant features for analysis. The process then branches into two parallel paths: Clustering, which involves categorizing like types of crimes into what is referred to as crime clusters, and classification which involves estimating crimes from past data within the Crime prediction. Finally, the outcomes of the two paths, and presented more visually in the visualization phase to facilitate interpretation and decision-making.

There are some important steps involved in crime prediction. The primary stage is data collection, where applicable information such as demographic data, crime rates, and climate data is gathered. This process, also known as data preparation, includes data cleansing and format conversion. Next, the preprocessed To build and assess the framework, data is divided between sets for training and test.

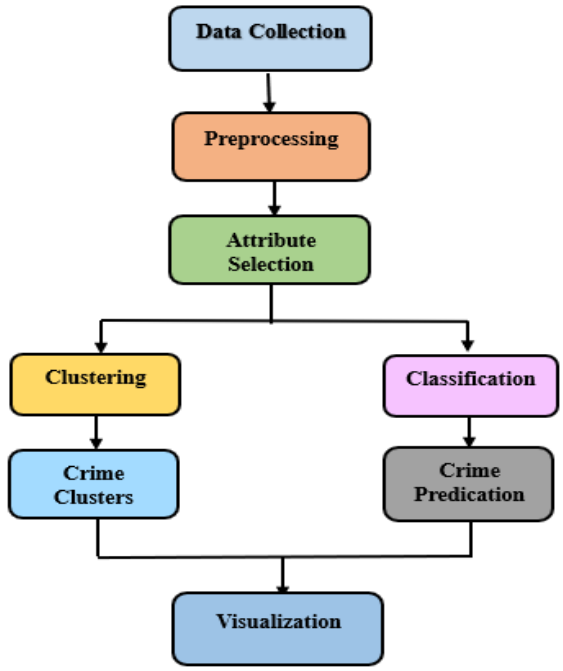

Figure 2: Crime Detection Framework

4. DEEP LEARNING IN CRIME PREDICTION

In recent years, Deep Learning has been adopted as one of the methods of crime prediction. Studies analyzing text, photos, audio, and data from social media available in the reference research articles include neural networks with convolution (The CNN network), deep neural networks, and analysis of sentiment. These algorithms can identify anomalies and trends in the data that may point to illegal conduct. Deep Learning's ability to manage large and complex datasets makes it highly suitable for crime prediction. Algorithms for picture analysis, for instance, can identify potentially dangerous items at crime scenes and forecast the possibility that a crime will be committed. Tweets related to criminal activity can be analyzed using

text-mining techniques to predict trends. Deep Learning algorithms can identify differences in corruption data from clever towns, potentially indicating criminal activity. As explained in the sections that follow, researchers employed these methods to address both classification and regression issues in crime prediction [7].

4.1. Crime Prediction with Deep Regression Models

Regression modeling with Deep Learning algorithms forecasts crime and identifies elements strongly linked to criminal activity. It also predicts future crime patterns.

A common theme among academic materials is the use of a regression analysis in combination with Deep Learning techniques, including order combining models, convolution-based neural systems, and deep neural networks with reiterated features for passion, to improve the reliability of crime forecasting [8][9].

The authors of studies on the prediction of theft crimes model the connection between Regression analysis of the environment, socioeconomic, and larceny crime data. A Temporal Spartoi Graph regression model estimates the probability of theft offenses in metropolitan areas using two Deep Learning models: an LSTM network and a Convolutional Neural Network (ST-GCN) [10].

Weather data, for example, can be incorporated into the regression model to affect crime trends. LSTM information's relationships with time are captured by modelling, while the spatial connections are captured by ST-GCN models. In a different article, the writers use analysis to model the association among crime statistics, the environment, and community television. The model for regression is a component of a complete multi-module strategy that predicts the risk of crime using methods of attention and sequential fusing models. There are four sub-modules in this framework, the first two of which handle temporal and spatial characteristics using St-BiLSTM and ATTN-LSTM [11]. Lastly, the data is abstracted and crime predictions are made using two fusion models on the crime datasets in San Francisco and Chicago. In a different study that focuses on exploiting spatial and temporal information, the authors create a regression model using convolutional neural networks on publicly accessible Los Angeles crime data [12]. The regression model is a component of a larger, mixed multimodal artificial neural network that is intended to forecast crime probabilities in real-time. The authors assert that improved precision and real-time performance are achieved by combining regression with the heterogeneous spatiotemporal neural network. By utilizing reversion to simulate the association among crime statistics and demographic characteristics from other areas, another study expands the prediction of crime risk to additional towns. The reversion perfect estimates the probability of criminal activity in new cities as share of an unstructured field version method.

In their studies, the authors note that a high % of accurate crime prediction is realized if regression is used in combination with the unstructured domain adaptation technique. Another research that was conducted in recent times employed Deep Learning as well

as machine learning approaches in assessing the crime rate in Xiaofan, a medium city [13][14]. The models capture geographical dependency (distance graph, point-of-interest resemblance, and crime comparison) using data on the climate, vacation, slot ID, and data year.

Using the temporal dependencies obtained from GRU, the occurrences in several fields are predicted by the number of occurrences in other fields. Regression is a versatile instrument that can be combined with extra methods to improve the accuracy of corruption forecasting models, as demonstrated by the referenced work. One more similarity is the use of such strategy as stemming to include extra information that may affect crime rates and to build the model of dependences between crime rates and other factors, such as weather indicators and demography. This approach enables the creation of detailed records and accurate crime trend models. Therefore, based on the overall findings shown in the five articles, it can be appreciated that regression analysis has several benefits when applied to crime prediction, such as the capacity to model more than one factor, combine with other sorts of analysis, and include extrinsic data influencing the crime rates."

4.2 Crime Prediction with Deep Classification Models

Deep Learning tools play a significant role in crime investigation by facilitating the classification of crimes and criminals. They also aid in analyzing big data to prevent different crimes and identify offenders. These systems can learn from multitudes of information types counting transcript, audio, film, and image data that enable them to recognize suspicious actions and other threats. For example, potential criminal activity can be identified by analyzing text or behavioral patterns associated with specific objects and using audio analysis, threat intonation, or certain accelerating keywords that may indicate criminal activity can be used. Also, video and surveillance data may be useful in controlling movement in public areas in real time, investigating strange movements, or, perhaps, finding objects that may be dangerous. Similarly, audio data can be highly useful in indicating unlawful conduct by revealing the tone of the message.

Another major benefit of Deep Learning in crime detection is its ability to process and analyze data patterns that may go unnoticed with conventional analytical methods. For instance, deep neural networks can be used in analyzing recorded videos of events such as the occurrence of some movements or actions that may be suggestive of criminal activities in a facility under surveillance. Likewise, it allows these systems to work through the amount of data, for instance, phone calls or retail transactions, to discover new relations that may indicate involvement in organized crime or fraudulent behavior. Thus, Deep Learning algorithms have delivered remarkable results in criminal detection. Two primary Deep Learning algorithm types are utilized in crime-related classification: (RNN) and (CNN) [15]. CNNs are frequently employed for image-based classification tasks, such as predicting crime scenes. CNNs are trained to identify potentially dangerous items, such as firearms, in crime scenes. According to the study on information

collected from crime scenes, these models can conduct in-depth analysis, identifying objects that may suggest wrong committed. On the other hand, analyzing periodic variations and patterns in data is a typical use of recurrent neural networks or RNNs. To improve predictive accuracy, for example, a study on crime prediction using behavioral tracking combines Deep Learning methods such as CNNs and RNNs to analyze mobility data and behavioral tracking data. The study demonstrates that by examining trends in the behavior and movements of people in a particular location, this method may accurately forecast criminal acts like theft and robbery.

Artificial neural network models are trained on criminal-related text data, particularly from social media, to forecast the likelihood of criminal activity. These models categorized patterns by analyzing the tone and context of the text. Other studies have also utilized Deep Learning methods for crime detection and forecasting. This work shows that Deep Learning can accept and handle text data, audio data, image data, and social media data for classification purposes about crime. For example, research about Criminal Anomaly Detection analyses the criminality patterns in smart cities through Deep Learning methods such as CNN and Autoencoders. As per the study, this method can precisely detect such anomalous patterns that might depict the existence of illegitimate actuation. The authors of a different study that employs both text and audio data present crime-related instances of exploitation with a combined Deep Learning model comprising CNN and BERT. This approach is useful when audio data that is being analyzed is available and provides a broad perspective on the crime event, as is the case with 911 calls, for instance. These study articles, in addition to others shown below, demonstrate how Deep Learning techniques, including CNN and RNN, can be used for crime categories and prediction based on various data types. Deep Learning algorithms have proven effective in this domain, providing insights into the determinants of crime. Thus, Law enforcement agencies can leverage these models to gain insights into criminal events and enhance crime prevention efforts.

Table 1. also gives a comparison of different methods used in crime analysis from the perspective of machine learning. The LSTM model discussed by Butt et al applied the Chicago crime dataset with an accuracy of 80%, and the paper is commended for the simple yet efficient approach [16]. ResNet-152 mentioned by Aziz et al., achieved a high-test accuracy of 99.87%; however, the dataset used was not specified, and this model is reported to be complex [17]. Wu et al. have another more complex LSTM model for daily origin-to-destination at the census tract level, although the authors stress not the accuracy, but the F1-score [18]. Last but not least, the CNN model presented by Gandapur et al., using the UCF-Crime dataset, reports 82.22% accuracy while being highly efficient for anomaly detection [19]. These techniques demonstrate different levels of efficiency in different aspects, such as datasets and problem complexity and the areas of focus; thus, they provide a view of their applicability to crime analysis tasks.

Table 1: The important summarized findings linked to user attitudes and behaviors

Techniques	Reference	Datasets	Results	Remarks
Long Short-Term Memory (LSTM)	Butt et al. [16]	Chicago crime datasets	80%	This model is simple and good
Residual Neural Network-152 (ResNet)	Aziz et al. [17]	Dataset is not mentioned	99.97%	This model is complex
Long Short-Term Memory (LSTM)	Wu et al. [18]	Daily origin-to-destination flows at the census tract (CT) level from January to December, 2020	Accuracy is not stated in this paper	F1-focused, accuracy not emphasized
Convolutional Neural Network (CNN)	Gandapur et al. [19]	UCF-Crime dataset	82.22%	Efficient anomaly detection achieved

5. DISCUSSIONS DISCUSSION, CHALLENGES AND FUTURE WORK

Criminal activity, a persistent challenge, has been addressed using emerging technologies to predict and detect criminality. These technologies have the potential to improve crime prediction methodologies by leveraging big data and advanced algorithms.

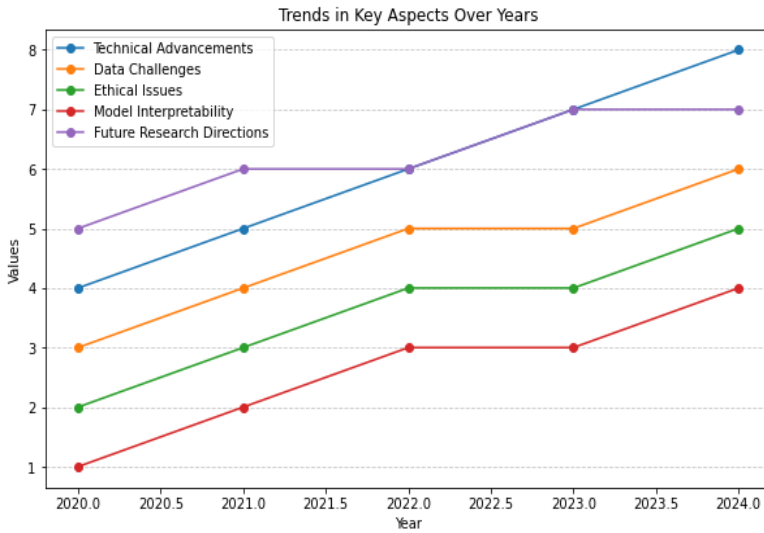

Figure 3: Trends in emphasis on key aspects of crime prediction research (2020-2024)

In this capacity, there is potential that these technologies can enhance the effectiveness and efficiency of crime prediction methodologies by combining big data and complicated algorithms [20].

Figure 3. shows the five aspect trends for the period 2020-2024, such as Technical Advancements, Data Challenges, Ethical Issues, Model Interpretation, and Future Research Directions. The horizontal axis shows the years of study and the vertical axis represents the corresponding values for each aspect of study.

The results reveal that all the aspects have been gradually increasing over time, which shows improvement. Technical Advancements started at a value of 4 in 2020 and are the projected to grow to 8 by 2024. Future Research Directions have consistently maintained high values throughout the study period as indicated in the table. Data Challenges, Ethical Issues, and Model Interpretability show similar trends, indicating growing interest and progress in these areas over time. However, even today much remains unknown about how exactly the issue of forecasting crimes may be solved with the use of such technology.

In this section, the future research agenda and potential benefits of technological advancement for crime forecasting will be discussed.

Technical advancements in crime prediction offers numerous advantages, particularly the capacity to spot patterns in criminal behavior by analyzing big databases. Advancements in surveillance and video analytical systems have been proposed and implemented to improve the accuracy and efficiency of criminal activity recognition. Due to real-time data analysis, police agencies can also take immediate action if criminal activity is taking place. Moreover, devices such as smartwatches and body cams, offer new opportunities for collecting and analyzing data on criminal activities. However, much remains unknown about how these innovations could be fully utilized crime forecasting. In this section, the future research agenda and potential benefits of technological advancement for crime forecasting will be discussed.

Technical advancements for crime prediction present many advantages, particularly the capacity to skim large numbers of records and classify trends in wrong conduct or action. The capacity to go through large datasets from diverse sources can provide meaningful insights into potential offenses. Further, advancements in surveillance and video analytical systems have been proposed and employed to improve the precision and effectiveness of criminal' activity recognition. Real-time data analysis enables police agencies to make immediate action during criminal activity. Figure 4. illustrate the frequency of the use of various deep learning algorithms in crime prediction. CNNs are the most used compared to

others because they excel at image analysis for crime scenes, while LSTMs and RNNs are used mostly where data is sequentially structured as in crime rates. Overall, combined approaches demonstrate high usage as they incorporate key aspects of various algorithms to improve predictions accuracy. Autoencoders reduce noise and detect anomalies while BERT [21] works with text based on crime as seen in crime applications above.

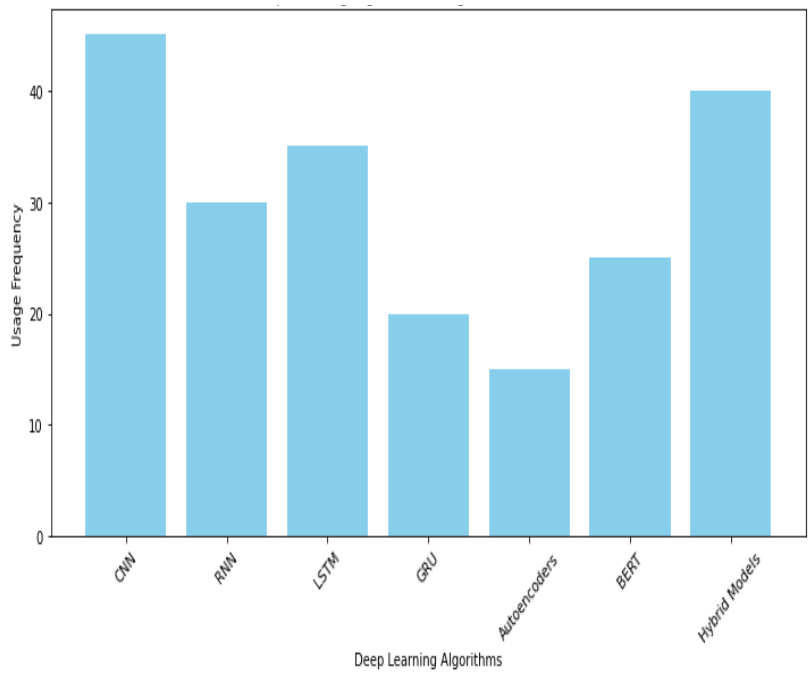

Figure 4: Deep learning algorithms usage frequency in crime prediction

The current research gaps and obstacles, such as the requirement for readable systems, reliable and precise information, moral issues, and more thorough assessments of their efficacy and accuracy, must be addressed to fully realize what is possible with these technologies. We can improve our knowledge of how technology affects crime prediction and help create more successful and effective policing tactics by filling up these gaps.

Created on the significance and present want of attention in the parts, we have depicted a variety of potential study directions in the field of neighborhood crime as an eventual research aim and agenda. The goal of early neighborhood crime recognition may be achieved by using the pertinent datasets that are accessible for such indicated future research issues [22].

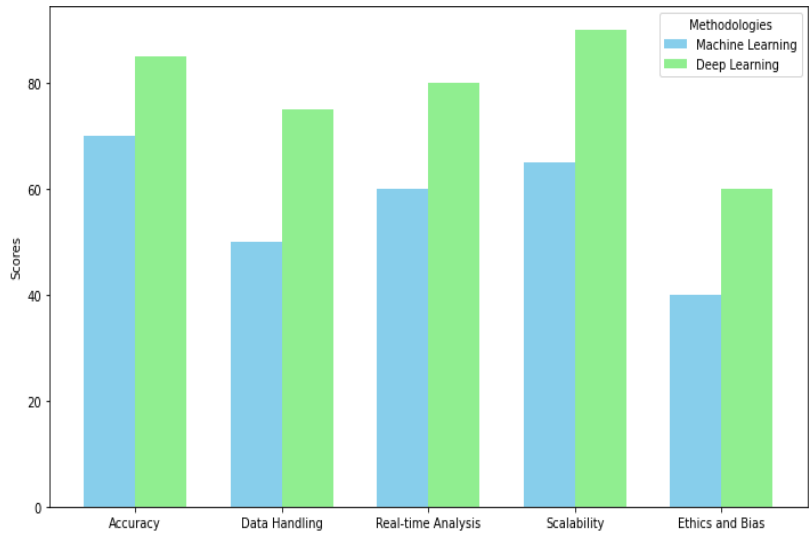

Figure 5: Comparison of Deep Learning and Machine Learning in Crime Prediction.

Figure 5. A bar chart associating the act of ML and DL in crime prediction across five key aspects: We also have five categories; Accuracy, Data Handling, Real-time Analysis, Scalability, and Ethics and Bias. It gives a quantitative value to represent the performance of both methodologies using predefined scores. All the bars are clustered adjacent to each other for a comparison of ML and DL, where the latter is represented in blue and the former in green. These are incorporated in the analysis to enable proper labeling to give it a clear title, label, or legend. The chart again points out that DL is slightly better in most classes because of its superior features.

In theory, goals provide a number of components near guide future investigations, supporting the endeavor toward recognize local crimes. Our methodical assessment provides a comprehensive hold of the traits and techniques employed by previous studies to identify illegal activities. Furthermore, we have listed several research questions that are both characteristic- & technique-oriented topic categories. In practical terms, this systematic review supports efforts for early crime detection by providing a roadmap for different scholars, professionals, those who respond, and criminal investigators should think about the characteristics and strategies that have been investigated to comprehend and detect crimes [23].

6. CONCLUSION

Researchers' interest in identifying

recurring patterns in crime has grown and this paper examines a various study on crime prediction approaches as technology and data analysis have advanced, it may be possible to improve the accuracy and success rate of crime forecasting algorithms by utilizing large amounts of data and sophisticated methodologies. The intricate nature of crimes takes grown lengthways with advancements in technology, generating challenging difficulties for rule implementation. Our findings help to clarify the consequences of these methods, but there is still a lack of thorough knowledge of how technological improvements can be completely utilized to tackle the crime prediction problem. The research community will also benefit from the emphasized datasets and suggested next directions as they pursue additional studies in the ground of crime prediction.

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