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Review of Crime Prediction Through Machine Learning

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Abstract: Older methods like documentation, investigative judges, and statistical research are ineffective for pinpointing exactly when and where the crime occurred. However, increased crime analysis and prediction accuracy significantly when machine learning techniques were included. The advancement of artificial intelligence (A.I.) and machine learning (ML) has resulted in new techniques for analyzing crime statistics. ML algorithms may quickly evaluate enormous amounts of data and determine emerging trends and patterns, which can assist law enforcement agencies in gaining a deeper understanding of criminal activity and developing strategies for its prevention. The prevention of crime can avert loss of life and property damage. Applying machine learning to crime prediction has been the subject of numerous in-depth academic studies. The most recent crime prediction methods that have been made public are reviewed in this study. The study aims to provide insight into how machine learning may improve crime prediction.

Keywords*: Machine Learning, crime prediction*

1. Introduction

In every society, crime is a pervasive concern [1]. Criminality is a deleterious global phenomenon in developed and developing countries [2]. It influences a society's quality of life and economic prosperity. It is essential to determine whether people should travel to a city or nation at a particular time or, if they choose to, which places they should avoid[3]. It is also an important indicator of a nation's social and economic development. Crime analysis is a crucial aspect of criminology that focuses on studying patterns of conduct and detecting criminals [4].

Nearly every sector of society, including law enforcement, has reaped the benefits of artificial intelligence, particularly data science and machine learning. Consequently, reducing criminal activity has always been a government priority. To contain the crime rate, law enforcement agencies employ legal methods. As global crime rates rise, law enforcement agencies continue to pursue advanced information systems that employ cutting-edge machine-learning techniques to protect their communities better. In many global regions, academia and industry are conducting substantial studies on evaluating and identifying crimes using machine learning [3].

While crimes can occur at any time and location, criminals typically operate within their familiar surroundings and seek to repeat successful activities under similar conditions [5]. It means that criminal acts frequently leave consistent traces. If those responsible for crime prevention identify this pattern of behavior, the crime may be prevented beforehand. Using machine learning algorithms to investigate and forecast crime gives security agencies a new perspective [6].

a. The Motivation of the Work

Although fewer crimes have been reported when there are more police present [10], police still need to be able to anticipate and deal with criminal activity efficiently, especially when it threatens personal or public safety. Intelligence is required for controlling and combating "intelligent" types of crime [11]; officers and other law enforcement forces could benefit greatly from intelligence when fighting all categories of crime. Data or information and a mechanism for analyzing the data are needed for intelligence. Incredibly large volumes of data are available from law enforcement authorities.

Artificial intelligence (A.I.), particularly machine learning, offers tools for increasing police awareness of existing and potential crimes and supporting sophisticated anti-criminal decision-making. Machine learning methods scale well with data volume [12].

Predicting future offenses can save lives and property. Using machine learning, numerous researchers have conducted thorough studies on criminal prediction. This study looks at the most recent and cutting-edge methods for predicting criminal behavior. This research aims to discuss how machine learning can help in crime prediction.

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b. Towered the Definition of the Crime

Based on severity, punishment, and guilt, crimes are typically divided into infractions, felonies, and misdemeanors. Violations include minor offenses such as tailgating, overstaying parking spaces, and racing. Currently, felonies are viewed as more serious than misdemeanors [13]. Crimes are also sorted into time-based categories, such as the month, week, day, and season, so data mining and ML can be used to anticipate when certain types of crime will occur. A database of past crimes committed in a certain area can be used. A wide variety of crimes vary in seriousness [14]. Three types of criminal offenses exist felonies, misdemeanors, and violations (sometimes known as wobblers) [15]. Crimes can be categorized in various ways, including victimization, victimlessness, and violence.

Professionals and government security officials need help foreseeing whether or not crimes will be committed. Researchers in computer science come into problems while using techniques like ML, data mining, and spatial-temporal data. The near-repeat-victimization and repeat-victimization approaches were used to forecast crimes in homes, towns, and regions between 2012 and 2016 [14].

Crime prediction has gained popularity recently because it improves investigators' computational capacity to manage crimes [2]. Concentrating the police's efforts on criminals requires better predictive algorithms [16]. Research has been carried out to forecast crime kinds, rates of crime, and hot locations using criminal datasets from various regions, such as South Korea and the United States [17]. Using the Canada dataset, other pilot programs are being broadened to determine specific crime concentrations, such as commercial and residential regions. The examination has centered on adopting cutting-edge methods such as ML and deep learning approaches [19] to prevent offenses with a rigorous process to preserve a safe environment. Nave Bayes, SVM, random forest, decision trees, and regression methods are the most recent examples of ML and deep learning algorithms employed to accurately predict crime and analyze [20].

Predicting crimes with any degree of accuracy is challenging, but it is essential if we want to stop them from happening. Accurately predicting the rate, types, and crime areas according to previous trends presents several computational opportunities and challenges. In prediction analysis, machine learning-based crime prediction is well-known, but few studies investigate machine learning techniques comprehensively. In some applications, like crime prediction, the ability of the ML method to handle non-linear rational data has been verified. With a faster training speed, it can extract properties from high-dimensional data [21]. Despite significant research efforts, the literature lacks relative accuracy for crime prediction using big datasets for different cities; datasets for Chicago and Los Angeles, for instance, have only been used on rare occasions. According to recent studies, multiple models have been shown to have difficulty predicting violent events, especially in high-crime areas [22].

Consequently, crime data usually originates from time series data, which demonstrates the seasonal character of the data and highlights the potential significance of varying criminal conduct over time. Developing a deep learning algorithm and visual patterns, specifically LSTM, that improves the classification of offenses based on appropriate metrics over time [23] also requires time series analysis. In addition, the present study suggests utilizing the ARIMA model for predicting crime trends [24].

2. Machine Learning

Statistical models and algorithms are used in machine learning, a type of artificial intelligence, to investigate data and generate predictions.

Multiple sectors are utilizing ML, a branch of A.I., to improve decision-making and forecast future occurrences [25]. ML investigates computer algorithms capable of self-improvement based on experience/learning and data. Four types of learning exist: supervised, unsupervised, semi-supervised, and reinforcement. AI consists of both computer and mathematical (statistical) elements [26]. Programming is performed so that the system can carry out a task usually linked with humans, and Artificial Intelligence (includes both computer and mathematical (i.e., statistical) components.

A system can learn on its own from the past without being explicitly designed because of a technique called machine learning (ML) [27]. A precise pattern or information cannot always be identified after viewing the data [28]. In these situations, machine learning (ML) is used to interpret precise patterns and data [29]. By providing machines with access to the correct data, ML encourages the notion that machines can learn and solve complex mathematical challenges and specific problems [30]. Unsupervised and supervised machine learning are the two main subcategories of ML, respectively [31].

In supervised learning, a predefined set of training illustrations is used to instruct the machine, which makes it easier for it to draw precise conclusions from new data [32]; in unsupervised learning, a set of data is provided,

and the machine is left to discover any patterns and connections on its own [33].

There are numerous ways to employ machine learning technology to solve the problem of crime prediction [34]. In crime prediction, machine learning algorithms have been applied to investigate crime data and identify future crime patterns. Based on crime data from specific cities, [35] algorithms such as decision trees, support vectors, and random forest machines have been devised to predict crime patterns accurately.

These algorithms can offer beneficial insights into crime patterns and trends in addition to forecasting crime patterns. Such abilities enable the efficient use of resources and strategies in the fight against crime. Furthermore, associations between criminal episodes and various geographical and demographic variables, including location, conditions, and time of day, can be found using machine learning algorithms [36]. This information can be used to develop strategies for crime prediction and prevention specifically suited to a certain community's needs.

Another major application of machine learning for crime prediction is predictive policing [37], which uses data and analytics to guide police efforts and lower crime rates. Algorithms for machine learning can evaluate crime statistics from a specific area, such as an urban area or surrounding area. With this understanding, law enforcement efforts will be more successful by concentrating the resources of law enforcement where they are most required.

3. Crime Prediction Using Machine Learning Techniques

As it would be difficult to anticipate crime manually, machine learning methods are increasingly used to anticipate and avoid crime. Historically, police departments have used "hotspot analysis" to prevent crime [38]. Adding prior crime and offense data to a map overlay enables police to deploy additional resources in these regions. However, this tactic is not preemptive; rather, it is a response to recent events. On the other hand, it might be useful to apply AI methods to police data in order to spot patterns and make predictions about future incidents. Using this data type, [39] looked into Vancouver's crime rates during a 15-year period. In order to identify potential hotspots for criminal activity, they employed a number of different AI methods, such as boosted decision trees with K-nearest neighbors.

Machine learning algorithms have traditionally proved efficient at predicting criminal behavior. Many models, such as logistic regression, decision trees, random forests, and support vector machines, are used to analyze crime data and determine trends that can be used to predict criminal behavior. Traditional machine-learning models need fewer data points and are simpler to understand. For instance, a logistic regression model may anticipate the likelihood of a specific crime occurring according to variables such as time of day, place of residence, and local population. The most critical factors contributing to a crime can be pinpointed by using a decision tree-based model. Random Forest (RF) models are capable of analyzing a variety of attributes and predicting crime trends. In addition to these techniques, conventional machine learning algorithms can analyze outliers and identify anomalies within crime data. By identifying anomalous patterns or deviations in the data, law enforcement agencies can identify potential illicit activity and take measures to prevent it.

Supervised and unsupervised learning are the two fundamental methods in AI and ML. Unlike unsupervised learning, supervised learning employs labeled data to predict outcomes accurately. There are additional distinctions, gaps, and significant areas in which one approach outperforms the other. Datasets teach computers how to recognize information or make predictions correctly. Moreover, classification and regression are the two data mining problems that belong under supervised learning.

- Test data is classified and categorized using an algorithm in Classification ML, which can tell the difference between cats and dogs. Another real-world example is recognizing malicious messages and storing them in a separate folder on your electronic mail client. Examples of classification machine learning algorithms include Support vector machines, decision trees, linear classifiers, and random forests.
- • Regression ML is supervised machine learning in which an algorithm determines the relationship between dependent and independent variables. Logistic regression, polynomial regression, and linear regression are the most used ML methods for regressing data. Moreover, regression models are created to determine numerical values.

  Unsupervised learning is a method for grouping and analyzing datasets without labels. Without human intervention, this method may reveal a hidden pattern in data. Additionally, this method may be divided into three categories: association, clustering, and dimensionality reduction.

- Clustering is a technique for classifying data without labels based on similarities or differences. For instance, the K-means algorithm assigns comparable information points to groupings (groups), where K indicates the group size.
- Linkage is an additional unsupervised form of machine learning that utilizes an array of principles to determine interconnections between dataset features.
- Reduced dimension is a programming technique used when a dataset contains numerous variables or features. The input data is reduced to a manageable size while maintaining data consistency.

The degree to which an algorithm applies labeled input and output data differentiates unsupervised learning from supervised learning. The training data provide the algorithm with repeated data predictions and corrective responses in supervised learning. Unsupervised learning aims to determine the structure of unlabeled data within an algorithm. Nevertheless, semisupervised learning, which is used when training data include both labeled and unlabeled information, is a technique that operates between the two. The semisupervised method is preferred if there are fewer labeled samples than unlabeled samples in a dataset. Despite the method's tedious nature, researchers continue to employ it.

4. Crime Prediction Process & Datasets

Using machines to predict crimes requires several key steps. The first stage is gathering data, which entails collecting pertinent information such as statistics on crime, population demographics, as well as weather conditions.

The data is then preprocessed, which entails activities like data cleansing and transformation into a usable format. Following data preprocessing, training, and testing, data sets for model construction and evaluation are produced. The following step is feature engineering, which entails selecting data characteristics that can be used to train the model. After it is the features have been chosen, multiple machine-learning algorithms can be implemented into the data for prediction and training. The models that have been trained are assessed using a variety of performance metrics to determine their predictive accuracy and crime-fighting efficacy. The research can be used to help guide policy choices in the areas of law enforcement and crime prevention.

Various data sets have been utilized in studies on crime detection and prediction. For instance, the Chicago Crime Dataset contains information on crimes reported in the metropolitan area of Chicago. This dataset was used to develop models that predict the likelihood of certain categories of crimes occurring in various urban areas. Another dataset used in crime prediction research is the London Crime Dataset, which includes information on crimes registered in London. This dataset has been used to build models that predict the probability of crimes occurring in particular geographic areas and their connection to socioeconomic characteristics, considering the geo-locations of persons.

In addition to the FBI Uniform Crime Report, the New York City (NYC) Crime Dataset and the Philadelphia Crime Dataset are also often used in crime detection and prediction studies. These datasets contain information on crimes reported in the locations to which they correspond. They have been used to develop models that predict the likelihood that specific categories of crimes will occur in various regions of the country. Also, global databases used to predict crimes in real time focus on CCTV images, types of violence, and firearms. These datasets offer academics useful data to create crime model predictions that could assist law enforcement entities in avoiding and responding to illicit behavior with greater efficiency.

5. Literature Review

The relationship between crime and society has led to extensive research on crime prediction, which uses machine-learning algorithms to address forecasting and prediction issues [14]. Academics have made numerous contributions to criminal investigation and prediction [25]. In contrast to most industries, including medical care, public transportation, the agricultural sector, finance, the retail sector, and service industries, crime prediction lacks structured and thorough research evaluations that can help summarize and organize existing literature, documentation, and challenges.

Recent research has examined crime prediction techniques. For instance, [40] studied data mining strategies for predicting criminality based on socioeconomic, spatial-temporal, population, and geographical attributes. Moreover, [41] presents an in-depth literature review in which the investigators give their findings on discovering and preparing for spatiotemporal crime clusters. They discussed the difficulties of creating a spatiotemporal crime prediction model and the role of machine learning (ML) and data mining (data mining) in identifying hotspots. In addition, [42] investigated several technological tracking solutions for crime prediction in intelligent communities. The scientists performed a comparison of a variety of criminal depictions. In accordance with the authors, numerous crime prediction methods and concepts have

been established, but field testing is necessary to ascertain their viability.

Researchers and developers can conduct studies and create accurate models for detecting and predicting crime hotspots due to the availability of vast crime data accumulated over the past few years. Studying crime trends and patterns has been a top priority for law enforcement agencies to formulate an effective policy for maintaining law and order using historical data. Predicting crimes based on historical data is a topic that has garnered great interest in numerous research disciplines, leading to the discovery of various aspects of crime detection.

Crime can be considered a location-based characteristic. This is because some locations pose a greater risk of criminal activity than others. Regardless of scale, it is evident that crime is not evenly, uniformly, or even randomly distributed within a given region, area, or city.

This is where mapping crime hotspots can be useful in figuring out why crime occurs there so frequently. The purpose of spatial and temporal data is to identify anomalies in criminal incidents.

Table 5 presents some recent studies that used machine learning techniques for crime detection and prediction.

Num	Study Purpose	Tool	Results
[44]	They used data mining to try to predict criminal activity. They found that due to crime's influence on societal and economic growth, data mining for crime prediction is a rapidly growing field of research.	Data mining	They stated that the data may be crime statistics for a particular location or region. In addition, they note that crime prediction studies can benefit the community by aiding authorities and government organizations in understanding the multiple factors that contribute to a crime's origin.
[45]	Predictions of tax crimes are the focus of this research. The study's authors believe their findings will lead to better decisions regarding St. Paul, Minnesota's service tax audit plans.	Machine learning, The investigators used Neural Networks, Decision trees, Nave Bayes, Ensemble learning, , Logistic regression and Random forests in their investigation. From 2016 to 2019, the researchers also collected manual face-to-face data on fiscal audits and plans.	Based on the findings, Random Forest has the highest accuracy at 66.2%. Governments can use machine learning to make improved decisions and strategies for tax audits. Predicting tax crimes allows governments to prepare for their occurrence beforehand. They determine that machine learning can predict crimes against legal systems and that such predictions can lead to enhanced decision-making and audit planning.
[46]	This study provided empirical evidence that machine learning algorithms are useful for predicting trends in violent crime and other related tasks, such as identifying crime hotspots or creating detailed profiles of individual offenders.	The utilization of Waikato Environment for Knowledge Analysis (WEKA), a freely available open-source software for data mining, has been employed. Three different methods, namely linear regression, decision stump, and additive regression, have been utilized to analyze neighborhoods and real crime datasets, employing a limited range of attributes.	This study aimed to undertake a comparative analysis of violent crime patterns derived from the Communities and Crime Unnormalized Dataset and actual crime statistical data.
[47]	This study aims to ascertain the efficacy and accuracy of a	The dataset was analyzed using supervised machine learning	This paper presents a methodology for predicting crime rates by

	machine-learning framework in forecasting instances of violent crimes. The main aim of this study was to evaluate the efficacy of machine learning algorithms in accurately predicting crime rates and explore their practical implementation, with a specific focus on the dataset used.	techniques to validate data, clean, and visualize the provided dataset.	utilizing a graphical user interface driven by machine learning algorithms. The comparative analysis of what occurred has been conducted to forecast the results of different supervised machine-learning algorithms.
[48]	To study the accuracy of crime prediction	For crime prediction and analysis, a unique crime detection technique known as naive Bayes was employed.	The researchers achieved an impressive crime prediction accuracy of 87%; nevertheless, they encountered limitations in applying their methodology to datasets, including a substantial number of features.
[49]	The study's contribution is to highlight the approaches employed in crime data analytics.	ML approaches such as KNN, naive Bayes, SVM, and clustering were utilized to classify, comprehend, and analyze datasets depending on predetermined conditions.	The suggested approach was created to perform various actions on the given datasets, including feature selection, clustering, analysis, prediction, and assessment. This study demonstrates the importance of machine learning approaches in predicting and evaluating criminal activity.
[50]	The model prediction was increased by including environmental context information through the utilization of a feature-level data fusion approach on deep neural networks.	The present study conducted an analysis of four demographic datasets pertaining to the year 2014. These datasets were obtained from reputable sources, including the City of Chicago Data Portal, American FactFinder, Weather Underground, and Google Street View.	As a result of training the area under the curve, precision, and recall, the effects were enhanced.

6. Conclusion

Around the world, crime is an issue that hurts society and impacts individuals daily. Crime has risen dramatically, particularly in urban areas, due to population growth and urbanization. It has been demonstrated that having more police officers hinders crime. However, they must possess the capability to anticipate and respond to criminal incidents, particularly those that pose a risk to the safety of individuals or the general public.

The utilization of machine learning algorithms for crime prediction or detection shows great potential as a viable solution to this complex issue. Through the utilization of extensive datasets and sophisticated algorithms, these technologies have the potential to enhance the precision and effectiveness of crime prediction models. Despite the developments in the industry, there is still a need to comprehend the potential utilization of these technologies in addressing the issue of crime prediction. One of the key benefits of machine learning algorithms in crime prediction is their capacity to examine extensive datasets and discern patterns or trends related to criminal behavior or activities. The algorithms have a significant potential to effectively handle vast quantities of data, encompassing information derived from social media platforms and various other online sources. This capability holds considerable advantages in detecting and revealing prospective illegal behavior. One significant benefit of employing machine learning and deep learning

techniques for crime prediction is its capacity to generate real-time prediction models. These algorithms possess the capability to predict and evaluate criminal data in real-time. This allows law enforcement organizations to respond swiftly to criminal activity. The study aimed to show how machine learning may enhance crime prediction.

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