Crime Prediction and Analysis Using Machine Learning

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***Abstract*—One of the most important problems affecting everyone around the world today is crime. In order to protect the worldwide population from falling victim to criminal or anti-social activity, the rate of crime should be reduced by utilizing various machine-learning approaches. Machine learning and artificial intelligence have recently demonstrated their value in practically every industry, and crime prediction is one of them. This requires keeping track of all crimes and creating a database for them that can be utilized as a resource in the future. In order to forecast and solve crimes in the future, it is currently difficult to keep an accurate record of crimes and analyze it. From a tactical point of view, the capacity to foresee any crime based on time, place, and other factors can assist in giving law enforcement crucial information. However, because crimes are increasing at an alarming rate, it is difficult to predict the crime effectively. Therefore, it is crucial to identify potential crimes now in order to prevent them in the future. The goal of this research is to evaluate a dataset that includes many crimes and make predictions about the kinds of crimes that could occur in the future depending on various factors. The dataset for this project contains data on crimes, including location details, the type of crime, the date, the time, the latitude, and the longitude. Data preprocessing will be performed prior to training the model, and this will be followed by feature selection and scaling to ensure high accuracy. For the purpose of crime prediction, the K-Nearest Neighbor (KNN) classification and several other machine learning algorithms will be tested, and the algorithm with the highest degree of accuracy will be used for training. Dataset visualization will take the form of graphical representations of various scenarios, such as when criminal activity rates are highest or which month has the highest criminal activity rates. The main goal of this project is to provide a basic understanding of how machine learning may be utilized by law enforcement organizations to identify, anticipate, and solve crimes considerably more quickly, which lowers the crime rate.**

***Keywords* —** Crime prediction, Machine Learning, K-Nearest Neighbor, Decision Trees, Support Vector Machine, Mean Squared Error

I. Introduction

Crime is a significant threat to humankind. Crime is among the main issues which are growing continuously in intensity and complexity [1]. Crime patterns are changing constantly and of which it is difficult to explain behaviors in crime patterns [2]. There are many crimes that happen at regular intervals of time. Perhaps it is increasing and spreading at a fast and vast rate. Crime is classified into various types like kidnapping, theft murder, rape, etc. Crimes happen from small villages and towns to big cities. Crime activities have increased at a faster rate and it is the responsibility of the police department to control and reduce criminal activities. Crime prediction and criminal identification are the major problems for the police department as there are a tremendous amount of crime data that exist. There is a need for technology through which the case solving could be faster. Law enforcement agencies collect crime data information with the help of information technologies(IT). Criminals usually operate as a part of a larger crime network and often are affected by the geographical and economic factors of that particular location. Therefore, by conducting a systematic study of criminal behavior, certain sets of statistical data can be developed. Identification of specific indicators helps in developing a database of historic crime data which can then use a machine learning approach to cure it at a certain level. Data visualization can be effectively applied to these criminal databases to produce important results about the region, the type, and the aim of the crime [3]. Analysis of crimes is the first stage in any study of crime. Crime analysis involves examining, comparing, and identifying connections between distinct crimes and their features. Crime analysis primarily comprises techniques and procedures aimed to lower the risk of crime. The method for locating and analyzing criminal patterns is practical. However, a fundamental problem for law enforcement organizations is to accurately and efficiently analyze the growing volume of crime data. So, without any computing support, it becomes a challenging task for crime analysts to analyze such vast amounts of crime data. Traditional crime analysis cannot be used when crime data is highly dimensional and complex queries have to be processed, necessitating the employment of a potent system for crime prediction. In order to successfully identify criminal patterns, a tool for crime prediction and analysis was required. This paper provides a few approaches that can be used to forecast which types of crimes are more likely to occur when and where they do. In order to identify features and forecast future trends in crime data based on similarities, classification is helpful. The K-Neighbour Classifier, Support Vector Machine (SVM), and Decision Tree Classifier are among the methodologies applied in this project. Data collection, data classification, pattern discovery, prediction, and visualization are significant stages in data analysis. The proposed framework uses different visualization techniques to show the trends of crimes and various ways that can predict crime using machine learning algorithms. The aim of this project is to make crime predictions using the features present in the dataset. The dataset is extracted from the official sites. With the help of machine learning algorithms, using Python as core we can predict the type of crime which will occur in a particular area. The objective would be to train a model for prediction. The training would be done using the training data set which will be validated using the test dataset. Building the model will be done using a better algorithm depending on the accuracy. Visualization of the dataset is done to analyze the crimes which may have occurred. In summary, we go over a theory in which we combine machine learning algorithms to serve as a database for all crimes that have been reported in terms of category, along with providing visual information about the environment through

Github link: https://github.com/vennela0609/Crime-Prediction-and-Analysis-Using-Machine-Learning

various techniques and using the knowledge of such data, we may predict a crime before it occurs.

II. Motivation

Crime activities have increased at a faster rate, and it is the responsibility of the police department to control and reduce criminal activities. Given the immense amount of crime data out there, crime prediction and criminal identity are the two biggest issues for law enforcement departments. The fundamental technique of identifying crimes before they happen is referred to as crime prediction. To predict a crime before it happens, you need the right tools. Police can now employ gadgets to help them with specific duties, such as deploying a body camera to film suspicious unlawful conduct or listening in on a suspect's phone call. Although these strategies are efficient, they all have one thing in common: they all function independently. Although the police can employ any of these strategies singly or simultaneously, having a device that can combine the advantages of all these technologies would be very helpful. A technological solution is required in order to help them speed up things. It can help them if they have any information such as criminal hotspots or regions with high concentrations of crime. The police department can benefit from the information gathered through data mining tools [4]. It is said in most research that machine learning has helped to find different patterns and relations among data. In order to gain meaningful insights from this data and understand how people and the world work, we need computational algorithms that can process the data and give us information that will be useful to us in a variety of ways.

III. Main Contributions & Objectives

The main objectives of this project are:

- Predicting crime before it takes place.
- Predicting hotspots of crime.
- Understanding crime patterns.
- Classify the kind of crime likely to occur based on location.
- Analysis of crime rate in different regions.

IV. Related Work

Numerous studies have been conducted to address the issue of reducing crime, and several crime-prediction algorithms have been put forth. The type of data used and the attributes used for prediction determine the accuracy of the forecast. In [1], mobile network activity was utilized to gather information on human behavior that was then used to predict the crime hotspot in London with an accuracy of roughly 70% when determining whether or not a given region in London city will be a hotspot for crime.

Data gathered from various websites and newsletters were used in [6] to predict and categorize crime using the Naive Bayes algorithm and decision trees, and it was discovered that the former performed better.

A thorough analysis of multiple crime prediction techniques, including Support Vector Machines (SVM) and Artificial Neural Networks (ANN), was conducted in [7], and it was found that no one technique can effectively address the issues associated with distinct crime datasets.

In [8], various supervised learning techniques, and unsupervised learning techniques [9] on the criminal records were done which address the connections between crime and crime patterns for the purpose of knowledge discovery which will help in increasing the predictive accuracy of crime.

Different approaches to prediction, including data mining, deep learning, crime casting, and sentiment analysis, were examined in [10], and it was discovered that each method has both advantages and disadvantages. Every technique produces superior results in a specific situation.

The criminal activity was detected using clustering techniques, and criminal activity was predicted using classification techniques [11]. The K-Means clustering was used, and the correctness of their performance is assessed. When comparing the results of various clustering algorithms, DBSCAN produced results with the best degree of accuracy, and the K-NN classification technique is used to predict crime.

Consequently, this technology aids law enforcement organizations in conducting accurate and better crime analysis. With the help of the data mining program WEKA, a comparison of the classification methods Naive Bayes and decision tree was carried out in [12].

The USCensus 1990 provided the datasets for this investigation. [13] examined the road accident pattern in Ethiopia while taking into account a number of variables, including the driver, vehicle, and road conditions. On a dataset with about 18000 data points, various classification techniques like K-Nearest Neighbor, Decision tree, and Naive Bayes were utilized. All three approaches have prediction accuracy ranging from 79% to 81%.

Using location and time data, the author in [14] has utilized a machine learning technique to forecast crime. There are no neighborhood cleansing rules applied to the dataset. The author has classified crimes according to their timing and location using San Francisco's crime statistics from 2003 to 2015. To describe the crime, the author utilized a variety of categorization models, including Adaboost, Random Forest, and K-nearest-neighbor. Adaboost decision is regarded by the author as the best classification model since it brought the highest accuracy when compared to other machine learning algorithms, and an accuracy of 81.93% is reached utilizing undersampled data. Although there are several drawbacks, the model can be used to generate crime locations on a geographical map which will be easier for the police to stop the casualties. Imbalanced classes are one of the major obstacles to reaching a better result [15]. The author was unable to find the major socio-economic cause of the crime.

According to the location, the K means clustering technique described by the authors in [16] can be used to anticipate where crimes would occur, allowing the authorities to take appropriate preventive action. K-means divides the data into clusters or groups based on the means, and the procedure is complete when the mean value becomes constant in the following iteration. On Kaggle, a participant described his method for grouping the information into crime-related groups using the clustering methodology. A dense cluster represents a large area that is likely to experience crime, and vice versa. The data can be evaluated using the provided methodology to show when crimes are most likely to occur, assisting the national police force in developing effective preventative strategies. Although the K-means technique is quick, it has some significant limitations, such as the dependence of the algorithm on initial values caused by selecting the initial value of K manually. It must be generalized if the clusters exhibit variability in size and density.

V. Proposed Framework

A. Predictive Modeling

Building a model that can make predictions is done through predictive modeling. A machine learning algorithm is used in the procedure to create those predictions by learning specific properties from a training dataset. Predictive modeling can be divided further into two areas: Regression and pattern classification [17]. In order to forecast the values of continuous variables, regression models are built on the investigation of relationships between variables and trends. The goal of pattern classification, in contrast to regression models, is to assign discrete class labels to a specific data value as an output of a prediction. A pattern classification problem in weather forecasting could be the prediction of a sunny, wet, or snowy day. This is an example of a classification model.

Tasks involving pattern classification can be split into two categories: supervised learning and unsupervised learning. In supervised learning, the classification model's input dataset's class labels are predetermined. In a supervised learning situation, we would be able to

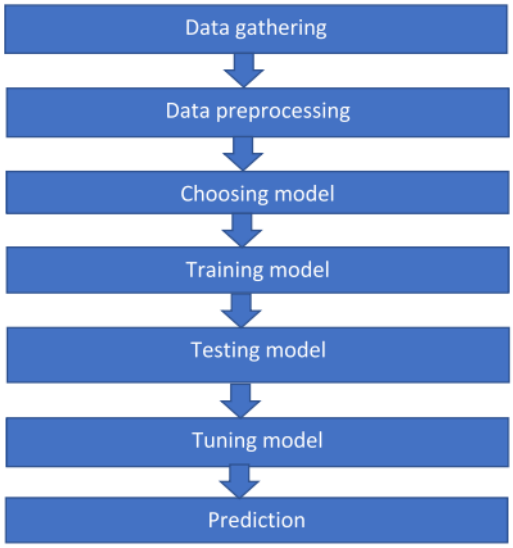

Fig. 1. Dataflow

anticipate outcomes for unobserved data by knowing which training dataset has the specific output that would be utilized to train. Types of predictive modeling algorithms are as follows:

a) Decision Tree: A decision tree is an algorithm that uses a tree-shaped graph or model of decisions including chance event outcomes, costs, and utility [17]. One of the most well-liked and effective tools for categorization and prediction is the decision tree [18]. It is organized like a tree, with each intermediate node representing a test on a particular peculiarity, each branch designating the test's outcome, and each leaf node containing the class label. Generally speaking, the desired variable is categorical. Decision trees are used to classify records or to determine the likelihood that a particular record belongs to each category. A Decision Tree is a supervised learning technique that can be used for both classification and Regression problems, but mostly it is preferred for solving Classification problems. In a Decision tree, there are two nodes, which are the Decision Node and Leaf Node. Decision nodes are used to make any decision and have multiple branches, whereas Leaf nodes are the output of those decisions and do not contain any further branches. The decisions or the test are performed on the basis of features of the given dataset. It is a graphical representation for getting all the possible solutions to a problem/decision based on given conditions. In order to build a tree, we use the CART algorithm, which stands for Classification and Regression Tree algorithm. A decision tree simply asks a question, and based on the answer (Yes/No), it further split the tree into subtrees.

Advantages of Decision Trees:

- It is simple to understand as it follows the same process which a human follows while making any decision in real life.
- It can be very useful for solving decision-related problems.
- It helps to think about all the possible outcomes for a problem.
- There is less requirement for data cleaning compared to other algorithms.

Disadvantages of Decision Trees:

- The decision tree contains lots of layers, which makes it complex.
- It may have an overfitting issue, which can be resolved using the Random Forest algorithm.
- For more class labels, the computational complexity of the decision tree may increase.

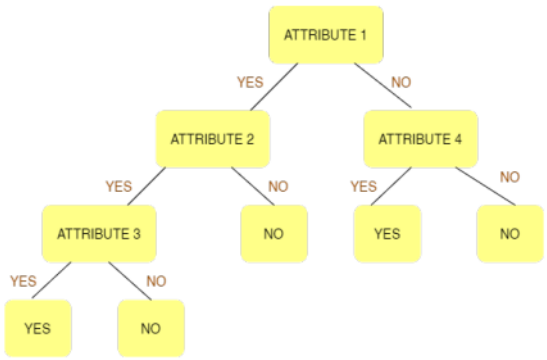

Fig. 2. Example of Decision Tree

b) Naive Bayes Classifier Algorithm: In machine learning, Naive Bayes classifiers are a family of simple probabilistic classifiers based on applying the Bayes theorem with independent assumptions between the features. The technique constructs classifier models that assign class labels to problem instances, represented as vectors of feature values, where the class labels are drawn from some finite set. Naive Bayes classifier is a probabilistic classifier which when given an input gives a probability distribution of the set of all classes rather than providing a single output. Compared to other algorithms like SVM (Support Vector Machine) which takes a lot of memory the easiness of implementation and high performance make it different from other algorithms. Research has shown that Naive Bayes shows more than 90% accuracy since it categorizes each word as tokens and removes frequent words like "the", "and", "of' etc which improves accuracy. A word is automatically terminated if it occurred fewer times or less than 3 times.

Advantages of Naive Bayes Classifier:

- It is simple and easy to implement
- It doesn't require as much training data
- It handles both continuous and discrete data
- It is highly scalable with a number of predictors and data points
- It is fast and can be used to make real-time predictions
- It is not sensitive to irrelevant features

Disadvantages of Naive Bayes Classifier:

- Naive Bayes assumes that all predictors (or features) are independent, which rarely happens in real life. This limits the applicability of this algorithm in real-world use cases.
- This algorithm faces the 'zero-frequency problem' where it assigns zero probability to a categorical variable whose category in the test data set wasn't available in the training dataset. It would be best if you used a smoothing technique to overcome this issue.
- Its estimations can be wrong in some cases, so you shouldn't take its probability outputs very seriously.

c) KNN Algorithm: The K-nearest neighbors(KNN) algorithm is a simple, supervised machine learning algorithm that can be used to solve both classification and regression problems [4]. It is used for finding the correlation between the test set and the train set. If the given test set is close to the training set then it is assigned the class label of the training set. The major limitation that emerges is when the training set has less number of data points. To enhance it diverse techniques like the KNN algorithm have been used. It finds its applications in data mining, intrusion detection, and pattern recognition. In this, the result is a member of a class. An object is categorized by a neighbor's mass votes, where the object is allocated to the most familiar of its k-nearest neighbors.

Given that the KNN technique just saves a training dataset rather than going through a training phase, it should be noted that it belongs to a family of "lazy learning" models. Additionally, this implies that all calculation takes place at the time a classification or prediction is being formed. It is also called an instance-based or memory-based learning approach since it significantly relies on memory to retain all of its training data.

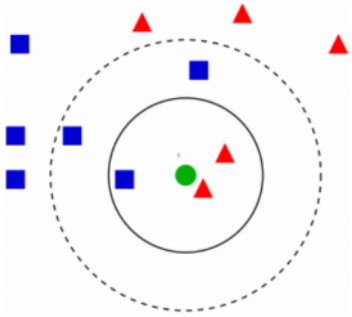

Fig. 3. Example of KNN

Advantages of KNN:

- Easy to implement: Given the algorithm's simplicity and accuracy, it is one of the first classifiers that a new data scientist will learn.
- Adapts easily: As new training samples are added, the algorithm adjusts to account for any new data since all training data is stored in memory.
- Few hyperparameters: KNN only requires a k value and a distance metric, which is low when compared to other machine learning algorithms.

Disadvantages of KNN:

- Does not scale well: Since KNN is a lazy algorithm, it takes up more memory and data storage compared to other classifiers. This can be costly from both a time and money perspective. More memory and storage will drive up business expenses and more data can take longer to compute.
- Curse of dimensionality: The KNN algorithm tends to fall victim to the curse of dimensionality, which means that it doesn't perform well with high-dimensional data inputs.
- Prone to overfitting: Due to the "curse of dimensionality", KNN is also more prone to overfitting. Lower values of k can overfit the data, whereas higher values of k tend to "smooth out" the prediction values since it is averaging the values over a greater area, or neighborhood.

VI. Data Description

Data is collected from Kaggle about the crimes that happened in India. It consists of a count of different kinds of crimes committed in a particular year in a particular district. The dataset consists of ten columns and 823 records. Each record contains attributes such as STATE/UT, DISTRICT, YEAR, RAPE, Kidnapping and Abduction, Dowry Deaths, Assault on women with intent to outrage her modesty, Insult to the modesty of Women, Cruelty by Husband or his Relatives, Importation of Girls. There are different data tables that consist of statistical information about various crimes. In this project, the frequency of crimes that occurred each year both district-wise as well as state-wise is mainly focussed. Later, for crime prediction, community-wise and population-wise data is being used to train and test the data using classification models. In each record of data, we have attributes like state/UT, district, the year, and the type of crime where the frequency of it is recorded. Data was in the right format except for a few null values which were to be handled. Most data that were fetched was already statistical which made it easier for the analysis. There was a count of different kinds of rapes that happened in a particular area in a particular year. There were proportions of population to crime which give the crime rate in a particular region. This can be used for further analysis when a new crime is reported to the police.

VII. Experimentation & Analysis

Data is collected in CSV format and is read using the pandas module. Then, the data is pre-processed by removing the null values and formatting the data if required. The categorical attributes are converted into numeric using Label Encoder. There exist some samples which are considered to be outliers, those samples have been removed by verifying them. The date attribute is split into new attributes like month and hour which can be used as features for the model. Based on the action to be taken, the feature selection is done which can be used to build the model. After feature selection location and month attributes are used for training. The dataset is divided into pairs of xtrain,ytrain, and xtest, ytest. The algorithms model is imported from skleran. Building of the model is done using model.fit (xtrain, ytrain). After the model is built using the above process, prediction is done using model.predict(xtest). The accuracy is calculated using accuracy_score imported from metrics - metrics.accuracy_score (ytest, predicted).

Model Selection: Based on the defined goal(s) (supervised or unsupervised) we have to select one of or combinations of modeling techniques. Such as KNN Classification, Logistic Regression, Decision Trees, Random Forest, Support Vector Machine (SVM), and Bayesian methods. In this project, KNN Classification, Decision Trees, and Naive Bayes modeling techniques are chosen. For each of the models, validate the assumptions of the respective algorithm. For training, the data is split in the ratio of 80% for training and 20% for testing using sklearn library. Develop or train the model on the training sample. After trying different combinations of parameters for each of the models different models were trained and their f-beta score and accuracy were calculated and the model with the highest accuracy is considered. Then the test set is also validated with the models using metrics like score and accuracy and the model that performs with good results is considered. For evaluating classification models that were implemented for the purpose of classification and prediction. The metrics used are accuracy and score. Precision is a measure that identifies positive cases from all the predicted cases.

$$Precision = \frac{TP}{TP + FP} \tag{1}$$

Next is the recall it measure which correctly identifies positive cases from all the actual positive cases.

$$Recall = \frac{TP}{TP + FN} \tag{2}$$

Accuracy is one of the most commonly used metric which measure all the correctly identified value without caring about the wrongly identified values. So, instead of using accuracy the measure that is used to check the performance is F-beta score.

$$Accuracy = \frac{TP + TN}{TP + FP + TN + FN} \tag{3}$$

Here TP stands for true positive, FP stands for false positive, FN stands for false negative, and TN stands for true negative.

Using matploltlib library from sklearn. Analysis of the crime dataset is done by plotting various graphs. A few visualizations were depicted which provide us with information such as the crime rate in each state in a year or the number of rape cases that were reported in the year based on the coordinates of the place or which age group has the highest number of victims and such. Various machine learning algorithms such as Decision Tree, Naïve Bayes, and KNN are put into use to predict the latest crime reports.

It is clear that basic details of criminal activities in a neighborhood contain indicators that will be employed by machine learning agents to classify a criminal activity given a location and date. The training agent suffers from imbalanced categories of the data set, it had been ready to overcome the problem by oversampling and undersampling the dataset. This paper presents a crime data prediction by taking the types of crimes as input and giving in which these crimes are committed as output using Colab notebook having python as a core language and python provides inbuilt libraries such as Pandas and Numpy through which the work will be completed faster and Scikit provides all the processes of how to use different libraries provided by the python. The results of prediction are different for different algorithms and the accuracy of the Random Forest Classifier was found to be good with an accuracy of 95.122%.

This research can be improved in the future to have more accurate classification algorithms that can identify criminals. To safeguard the data set we are using, we can also strengthen privacy and take additional security precautions. Additionally, this research may be expanded in order to predict criminals, and this can be done utilizing face recognition. If there is any suspicious change in the behavior or routine motions, the system will alert you. For instance, if a person is repeatedly traveling back and forth in the same area, it may be a sign that they are pickpocketing, and it will also monitor them over time.

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