CRIME DATA ANALYSIS

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Abstract
In the realm of data science, predictive analytics has become an invaluable tool for various sectors, including law enforcement. This paper explores the development and implementation of a web application designed to predict the likelihood of different types of crimes based on historical data. Utilizing machine learning models, the application processes inputs such as the day of the week and specific locations to provide users with predictions of crime probabilities. This innovation aims to enhance crime prevention strategies by offering timely insights into potential crime occurrences. Crimes have a negative effect on any society both socially and economically. Law enforcement bodies face numerous challenges while trying to prevent crimes. We propose a Crime Data Analytic Platform (CDAP) to assist law enforcement bodies to perform descriptive, predictive, and prescriptive analysis on crime data. CDAP has a modular architecture where each component is built separate from each other. CDAP also supports plugins enabling future feature expansions. The platform can ingest any crime dataset which has the required attributes to map dataset to attributes required by the platform. It can then analyze them, train models, and then visualize data. CDAP also combines census data with crime data to achieve more comprehensive crime analysis and their impact on society. Moreover, with the combination of census data and crime data, CDAP provides process reengineering steps to optimize resource allocations of police forces. We demonstrate the utility of the platform by visualizing spatial and temporal relationships in a set of real-world crime datasets. Predictive capabilities of the platform are demonstrated by predicting crime categories, for which a machine learning approach is used. Identification of optimized police district boundaries and allocating patrol beats are used to demonstrate the prescriptive analytics capabilities of the tool. Heuristic-based clustering approach was taken to define police district boundaries in a way that the identified districts have equitable population distribution with compact shape. The resulting districts are then evaluated on inequality of population and the compactness using Gini Coefficient and Isoperimetric Quotient. Another heuristic-based approach was taken to define new police patrol beats to be optimized on equitable workload distribution, compactness, and minimizing response time for new police patrol beats

I. Introduction

Background

Crimes are a social nuisance and it has a direct effect on a society. Governments spend lots of money through law enforcement agencies to try and stop crimes from taking place. Today, many law enforcement bodies have large volumes of data related to crimes, which need to be processed to turn into useful information [3]. Crime data are complex because they have many dimensions and in different formats, e.g., most of them contain string records and narrative records. Due to this diversity, it is difficult to mine them using off the shelf, statistical and machine learning data analytics tools.It is the primary reason for lack of general platform for crime data mining. While there are some propitiatory platforms to predict and analyze crime data, they are focused only on certain areas of crimes, not

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extensible, and do not provide an API to integrate with other tools [4]. Moreover, the same tool cannot be used for the analysis and well as planning such as patrol beads and district boundaries.

Motivation

High or increased crime-levels make communities decline, as crimes reduce house prices, neighborhood satisfaction, and the desire to move in a negative manner [5]. To reduce and prevent crimes it is important to identify the reasons behind crimes, predict crimes, and prescribe solutions. Due to large volumes of data and the number of algorithms needed to be applied on crime data, it is unrealistic to do a manual analysis. Therefore, it is necessary to have a platform which is capable of applying any algorithm required to do a descriptive, predictive, and prescriptive analysis on large volume of crime data. Through those three methodologies law-enforcement authorities will be able to take suitable actions to prevent the crimes. Moreover, by predicting the highly likely targets to be attacked, during a specific period of time and specific geographical location, police will be able to identify better ways to deploy the limited resources and also to find and fix the problems leading to crimes. Several applications are already developed for crime analysis .Most of these tools are developed to help the police to identify different crime patterns and even to predict criminal activities. They are complex software which needs a lot of training before use. Designing a tool which is easy to use with minimal training would help law-enforcing bodies all around the world to reduce crimes.

Literature review

Section 2.1 defines crimes and related theories. Existing platforms and importance of a platform which is able to carry out descriptive, predictive, and prescriptive analytics of crime data are discussed in Section 2.2. Section 2.3 discusses about the infrastructure, tools, algorithms, visualization, and different types of architectures related to the solution.

Crimes

1.1.1 Crimes and Effect on the Society

A crime can be defined as any action or omission that violates a law, which results in a punishment. Usually what constitutes as a crime depends on the government bodies and laws that are in existence in those places. To understand the nature of crimes, one has to understand not only its spatio-temporal dimensions, but also the nature of the crime, the victim-offender relationship, role of guardians, and the history of similar incidents [8].Regardless of the reasons why crimes take place, they put a strain on the communities, towns, and cities. Usual monetary costs associated with them include cost of policing crime and prosecuting those who commit crimes. Non-monetary costs consist of social costs, where they affect the quality of life, mental health, and physical security of people living in those areas. Crimes are a social nuisance and being able to solve them faster is very important and will pay for itself [4].

1.1.2 Criminology Theories

According to John and David [9], theories of crimes can be divided into two categories namely, those that seek to explain the development of criminal offenders and those that seek to explain the development of criminal events. Criminology has been mainly developed through theories and research on offenders. Only recently it has begun to explain the crimes rather than criminality of people involved in it. Criminology consists of many theories that explain how and why some offenders act in the way they do. Following are some of theories that explain how places are associated with crimes [9].

1. Rational Choice Rational Choice suggests that offenders will select targets and define means to achieve their goals in a manner

that can be explained. Further it can be explained as that human actions are based on rational decisions, that is they are informed by probable consequences of that action [9].

2. Routine Activity Theory This theory explains the occurrence of crimes as the result of several circumstances. Namely, a motivated offender, a desirable target, target and offender must be at the same place at the same time, and lastly absent of other types of controllers intimate handlers, guardians, and place managers [9].

3. Crime Pattern Theory This theory combines the above two theories and goes on to say that how targets come to the attention of offenders is influenced by distribution of crime events over time, space, and among targets. An offender will come to know of criminal opportunities while engaging in their day-to-day legitimate work. So a given offender will only know about a subset of available targets. The concept of place is essential to crime pattern theory [9].

Having an understanding of criminology theories is essential to try and create crime analysis tools or platform using modern technologies.

PROPOSED METHOD

The platform which is going to be developed directly targets the crime domain. It has the ability to analyze crime data in three different ways, namely Descriptive, prescriptive, and predictive analytics. The most important part of this platform is that, it is designed to be scalable to support different types of crime data analysis. Different user requirements can be achieved through developing simple plug-ins to the system and scale the platform.

Descriptive Analyzer use both quantitative and qualitative data along with analytical techniques. Qualitative data and analytical techniques refer to non-numerical data, as well as the examination and interpretation of observations for the purpose of discovering underlying meanings and patterns of relationships. Descriptive analyzer basically provides relationships between crimes and identifies the pattern of crimes and temporal and spatial relationships between crimes. It also provides statistical summary of a given data set. Prescriptive analyser tries to identify the reason behind the crimes and gives the suggestions to avoid or reduce the crimes. It has the ability to identify significant factors related to the crimes committed. Through plugins users can manipulate and extend the platform for specific needs.

In this platform, predictive analytics methods are mainly used for predicting category of a crime which can be occurred somewhere at a given time. Predict crime category system integrates population and race data accordingly to the given crime data set. Using machine learning techniques it can predict the category of crime that can occur. Any user or a law enforcement body, who has crime dataset can use this feature to understand the severity of crime that would take place, and as a result could take necessary steps to allocate resources effectively. Following sections describe about the architecture and different modules implemented in the solution.

Proposed Design and Solution

The proposed design and solution for the web application aimed at predicting crime probabilities leverage modern

machine learning techniques and web technologies to deliver accurate, real-time crime predictions. The following sections outline the design components, architecture, and workflow of the solution.

1. System Architecture

The architecture of the proposed system is composed of three primary layers:

1. Data Layer:

- Data Collection: Historical crime data is collected from various sources, such as police records, public databases, and other relevant datasets.

- Data Storage: The collected data is stored in a structured database that supports efficient querying and retrieval. This could be a relational database like PostgreSQL or a NoSQL database like MongoDB.

- Data Preprocessing: Data cleaning, normalization, and feature extraction are performed to prepare the data for model training. This involves handling missing values, encoding categorical variables, and scaling numerical features.

2. Model Layer:

- Machine Learning Models: Various machine learning models, such as logistic regression, decision trees, random forests, or neural networks, are trained using the preprocessed historical crime data. The models are selected based on their performance and ability to handle the complexity of the crime data.

- Model Training and Validation: The models are trained on a portion of the data and validated using another portion to ensure they generalize well to unseen data. Performance metrics such as accuracy, precision, recall, and AUC-ROC are used to evaluate the models.

- Model Deployment: The best-performing model is serialized and saved for deployment. This model will be used by the web application to make predictions.

3. Application Layer:

- User Interface: A user-friendly web interface is developed using modern web technologies such as HTML, CSS, JavaScript, and frameworks like React or Angular. The interface allows users to input data points such as the day of the week and location.

- Backend: The backend server, built using frameworks like Django or Flask, handles user requests, processes input data, interacts with the machine learning model, and returns the predictions to the frontend.

- API Integration: The backend provides APIs for model predictions, allowing the frontend to communicate with the model and retrieve results.

2. Workflow

The workflow of the proposed solution is as follows:

1. User Input:

- The user accesses the web application and inputs the required data points, such as the day of the week and specific location.

2. Data Processing:

- The backend server receives the input data and preprocesses it to match the format required by the machine learning model. This involves encoding categorical variables (e.g., day of the week, location) into numerical format.

3. Model Prediction:

- The preprocessed data is fed into the deployed machine learning model, which generates probabilities for various types of crimes that might occur based on the input data.

4. Result Display:

- The predicted probabilities are sent back to the frontend, where they are displayed to the user in a clear and interpretable manner. The interface may include visualizations such as charts or graphs to enhance understanding.

5. Continuous Learning:

- The system continuously collects new crime data and updates the model periodically to improve its accuracy. Feedback mechanisms are also integrated to refine the model based on user interactions and new data.

3. Advantages

The proposed design offers several advantages over traditional crime prediction methods:

- **Accuracy:** Machine learning models can capture complex patterns and relationships in the data, leading to more accurate predictions.
- **Automation:** The system automates data processing and prediction generation, reducing manual effort and increasing efficiency.
- **Real-time Predictions:** The application can provide real-time predictions based on the latest data, allowing for timely and proactive crime prevention measures.
- **User-friendly Interface**: A well-designed web interface makes it easy**4.2.2 Proposed Algorithm**

The proposed algorithm for predicting crime probabilities is designed to effectively leverage historical crime data and user input to generate accurate and actionable predictions. The algorithm involves several key steps, including data preprocessing, feature extraction, model training, and prediction generation. Below is a detailed breakdown of each step in the proposed algorithm.

Step 1: Data Collection and Preprocessing

1. Data Collection:

- Gather historical crime data from reliable sources, including police reports, public crime databases, and other relevant datasets.
- Ensure the data covers a comprehensive range of features, such as date, time, location, type of crime, and other relevant variables.

2. Data Cleaning:

- Handle missing values by either imputing them with appropriate statistics (mean, median, mode) or by removing incomplete records if necessary.
- Remove any duplicate entries to ensure the dataset's integrity.

3. Data Normalization:

- Normalize numerical features to ensure they are on a similar scale, which helps improve the performance of machine learning models. Techniques such as min-max scaling or standardization can be used.

4. Feature Encoding:

- Encode categorical variables, such as the day of the week and location, into numerical format using techniques like one-hot encoding.
- Extract additional features that may be relevant to the prediction task, such as time of day, proximity to certain landmarks, or weather conditions.

Step 2: Feature Selection and Engineering

1. Feature Selection:

- Identify the most relevant features for predicting crime probabilities using techniques such as correlation analysis, mutual information, or feature importance scores from tree-based models.

2. Feature Engineering:

- Create new features that may capture important patterns in the data. For example, combining date and time information into a single temporal feature or aggregating crime counts over specific time windows.

Step 3: Model Training

1. Splitting the Data:

- Split the data into training, validation, and test

sets to ensure the model's ability to generalize to new, unseen data.

2. Model Selection:

- Experiment with various machine learning algorithms, such as logistic regression, decision trees, random forests, gradient boosting machines, or neural networks, to identify the best-performing model.
- Use cross-validation to evaluate the models' performance and select the one that provides the best balance between bias and variance.

3. Model Training:

- Train the selected model on the training data, tuning hyperparameters as needed to optimize performance.
- Validate the model on the validation set to fine-tune hyperparameters and prevent overfitting.

4. Model Evaluation:

- Evaluate the final model on the test set using performance metrics such as accuracy, precision, recall, F1-score, and AUC-ROC to ensure its robustness and reliability.

Step 4: Prediction Generation

1. User Input Processing:

- Accept user inputs through the web application, such as the day of the week and location.
- Preprocess these inputs to match the format of the features used in the model (e.g., encoding categorical variables).

2. Prediction Computation:

- Feed the preprocessed user inputs into the trained model to generate predictions.
- The model outputs a set of probabilities indicating the likelihood of various types of crimes occurring based on the input data.

3. Result Presentation:

- Present the predicted probabilities to the user in a clear and interpretable format. This may include visualizations such as bar charts or probability heatmaps to enhance understanding.
- Provide additional context or recommendations based on the predictions to assist users in making informed decisions.

Step 5: Continuous Improvement

1. Model Retraining:

- Continuously collect new crime data and periodically retrain the model to ensure it remains up-to-date and accurate.
- Incorporate feedback from users to refine the model and improve its performance.

2. Monitoring and Maintenance:

- Monitor the system's performance in real-time to detect any issues or degradation in accuracy.
- Perform regular maintenance and updates to the underlying infrastructure and algorithms to ensure the system's reliability and scalability.

The proposed algorithm for predicting crime probabilities combines comprehensive data preprocessing, advanced feature engineering, robust model training, and user-friendly prediction generation to deliver a powerful and effective solution. By leveraging historical data and user input, the algorithm can provide accurate and actionable crime predictions, helping law enforcement agencies and the public to proactively address and prevent criminal activities.

RESULT

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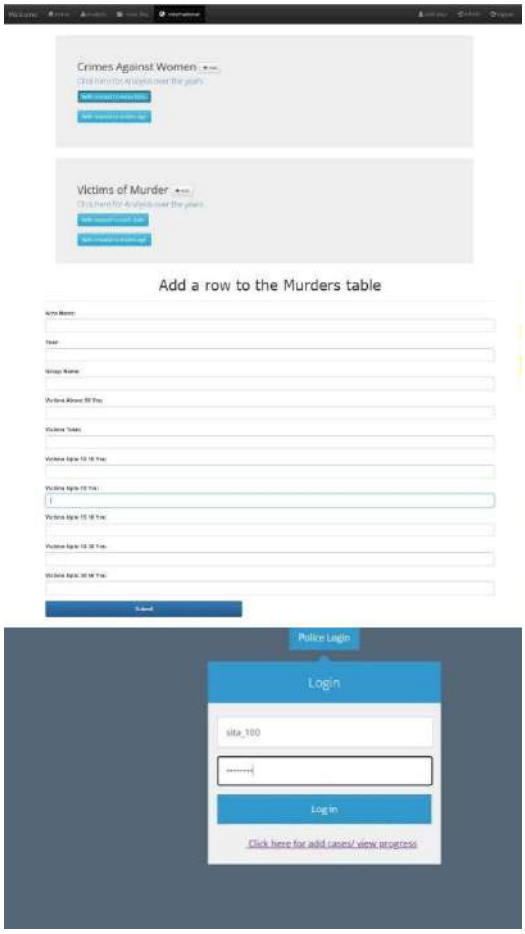

CONCLUSION

This project has successfully developed a machine learning-based crime prediction model that aims to enhance public safety by forecasting potential crime occurrences in specific locations and times. By leveraging historical crime data and various environmental factors, the model identifies patterns and trends that can assist law enforcement in resource allocation, patrol planning, and crime prevention strategies. The approach used in this project has demonstrated the potential for machine learning models, specifically classification algorithms, to provide actionable insights into crime prediction. By incorporating features such as the day of the week and the location of incidents, the model effectively predicts the likelihood of various crime types occurring in different areas, offering valuable support to crime analysts and law enforcement officers.The results show that the model is capable of delivering reasonable predictions, though there is room for improvement in terms of handling imbalanced data, incorporating more granular features (such as socio-economic and weather data), and refining the prediction of rare crime types. These improvements could lead to even more accurate and reliable predictions, making the system more effective in real-world applications.Furthermore, the project highlights the importance of integrating machine learning systems with real-time data sources and adaptive models that can evolve over time to account for shifting crime patterns. Future work will focus on enhancing the model's scalability, adaptability, and real-time prediction capabilities, while also addressing ethical and privacy concerns related to the use of sensitive data.

In conclusion, this project lays a strong foundation for the use of predictive analytics in crime prevention and law enforcement strategies. As machine learning techniques continue to evolve, the potential for using predictive models in public safety and criminal justice systems is vast, offering opportunities to reduce crime rates, optimize law enforcement efforts, and ultimately improve the quality of life in communities.

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