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Monitoring The Impact of Social Factors on Crime using Machine Learning

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Abstract

Due to the population growth crime rate is increasing, which is a great challenge for the police department. Crime analysis is a systematic way of detecting and investigating patterns and crime trends. In our work, we focus to find the effect of social and economic factors on uniform crime statistics data set. Afterwards, this study introduces a machine learning technique that uses uniform crime statistics data set to measure the impact of social and economic factors on crime in the USA. In this work, we first monitor the effect of poverty and unemployment on four crime types (robbery, property snatch crime, burglary, and motor vehicle snatch).

This work is based on crime, social and economic factors of the USA data set. Secondly, the effect of GDP, GDP per capita, imports, exports, urban growth, unemployment, and inflation on the total crime of the USA from 1960 to 2012 was determined. K Nearest Neighbor, Support vector regression, Multilayer Perceptron, Linear Regression, and gradient boosting have been applied, and a comparative analysis between these techniques has been performed. The MSE rate of linear regression is lower than SVR and has a high coefficient of determination value in the first experiment. Multilayer Perceptron achieved low MSE and high r square in predicting the impact of economic factors on the total crime of the USA. The experimental results conclude that unemployment affects robbery crime.

Keywords: Crime Analysis, Machine Learning, Economic and Social factors

Introduction

Crime is a hurtful demonstration and behavior that violates the law. Around the globe, all states wish to overcome the crime rate by imposing the law. But it is necessary to know the reason for the crime. It helps the state to overcome the factors that influence the crime. There are certain factors like unemployment, poverty, inflation, and literacy rate that affect the different types of crime such as robbery, burglary, and motor vehicle snatch. The main aim of this research is to find how social and economic factors influence crime rates. Machine learning techniques were applied to crime data to predict and gauge crime designs.

In the past, researchers proposed solutions to identify the factors that influence the crime rates. Mamta Mittal et al. predict the impact of unemployment and GDDP on burglary and robbery. and theft using RF, ANN, and decision tree [1]. Alif et al. used uniform crime statistics data set to forecast the crime rates. They perform multivariable regression analysis using SVR, RF, and ANN and forecast total crime rates based on different economic factors [2]. Prashant L. Chintal et al. predict and analyze cybercrime trends for the future in the Maharashtra state of India using Linear Regression [3]. In our proposed work, we monitor the impact of unemployment and numbers below the poverty line on robbery, burglary, property snatch crime, and motor vehicle snatch. Secondly, we monitor the impact of GDP, GDP Per capita, imports, exports, urban growth, unemployment, and inflation on the total crime of the USA. In our research, machine learning algorithm such as K Nearest Neighbor, linear regression, Multilayer Perceptron, Gradient Boosting, and Support Vector Regression is implemented to analyze crime of USA states.

The rest of the paper has been organized as follows: Section II provides a brief survey of the researcher's past work on crime prediction. In sections III and IV, a brief introduction of machine learning and the proposed methodology of this work are explained. In section V, results are presented and compared. In section VI, Conclusions are presented.

Literature Review

The researcher proposed various solutions for the analysis and prediction of crime using machine learning techniques. Mamta Mittal et al. predict the impact of unemployment and GDDP on burglary, robbery, and theft. They used linear regression, random forest, neural network, and decision tree to predict the economy's effect on each crime type based on unemployment and GDP. The experimental results show that Linear regression, random forest, neural network, and decision tree accuracy are 93.50649, 90.90909, 92.20779, and 92.20779 respectively [1].

Alif Ridzuan Khair ud din et al. perform a comparative analysis of ANN, SVR, RF, and gradient tree boosting on crime data to forecast crime rates. The experimental result proves that Gradient Tree Boosting shows the highest predictive performance and the lowest errors compare to ANN, SVR, and RF [2]. Luiz et al. predict the crime and quantified the influence of urban indicators on homicides using Random Forest. This approach achieved 97% accuracy on crime prediction [3].

Lian Duan et al. predict the crime risk of each region using the novel "Spatiotemporal Crime Network in the urban area for the next few days. They apply DCNN for automatically crime-referenced feature extraction. The author evaluated the STCN using felony and 311 datasets in the state of USA New York City from 2010 to 2015. The experimental result shows that STCN achieved 88% F1 and 92% AUC [4].

Bao WANG et al. predict the distribution of crime in Los Angeles using the spatial-temporal residual network. They compare several existing approaches in crime prediction and demonstrate the superiority of the proposed model in terms of accuracy [5]. Prashant et al. predict and analyze cybercrime trends for the future in the Maharashtra state of India. They used linear regression with a gradient descent approach for predicting the future crime which supports minimizing the cost function. District wise cybercrime estimation test is performed for different types of the future trend of cybercrimes based on geographical information [6].

Mrinalini Jangra et al. perform crime prediction of certain states in India. K Nearest Neighbor was applied for the prediction of crime. It was analyzed that the KNN classifier has less accuracy 77.18 and higher execution time. They applied a naïve Bayes classifier and improved the accuracy of crime prediction 96.48[7].

Gnaneswara et al. addressed the problem of early crime prediction from a model. The model identifies a future crime. They used the Lesso technique for feature selection and applied a naïve Bayes classifier. The experimental results show that naïve Bayes achieved accuracy 97.47 [8]. A. Abdo et al. make a system that will help the Egyptian government to make strategic decisions to reduce crime. The Proposed work consisted of six stages. These are data preprocessing, building the proposed data warehouse, extract transform and load data into a data warehouse, fourth is applying data mining techniques and fifth is the evaluation of the proposed system and finally, the result displaying. A naive Bayes classifier was applied. The resulting accuracy of naïve Bayes is 98% [9].

Ravi Kumar et al. predict the future crime incident using big data's technique to handle a huge amount of data and use naïve Bayes classifier. The experimental findings conclude that naïve Bayes achieved better results in finding the potential solution and crime pattern. The author achieved the highest accuracy on property crime which is 74.46% [10].

Pankaj Kushwaha et al. proposed a system that finds the suspect easily based on crime data sets attribute like name, location, weapons used, date of crime, and type of crime and it very helpful to the investigator. They used a naïve bayes classifier. The result of this system is the maximum probability of the suspect and the crime type [11]. Jesia Quader et al. proposed a system that analyzes the patterns of crime. The purpose of this article was to predict which crime category is most probable happening in a Chicago city at which place and time. They used an Extra Tree, Bagging, random forest, AdaBoost, and decision tree to evaluate the accuracy given by each algorithm. Decision Tree, AdaBoost, Bugging and extra tree accuracy is 99.88%, 74.78, 79.92% 97.0%, and 95.99% [12].

Shiju Sathyadevan et al. predict the region which has a high probability for crime occurrence and visualize the high crime-prone area. Naive Bayes, Apriori algorithm, and decision tree were applied to predict crime occurrence. The decision tree gave better results among other classifiers [13]. Emmanuel et al. made a system for law enforcement and intelligence agencies for crime analysis with better performance from the existing. Data mining is a way of extracting the hidden pattern and relationship among data. They use a decision tree classifier. The experimental result shows that the J48 algorithm predicts the crime category with 94.25\% accuracy [14].

Vrushali Pednekar et al. find out the crimes that are occurring most frequently. In this work, K-Nearest Neighbor (KNN) classifier was used. The proposed system predict region who has high crime occurring probability and forecast high crime-prone areas [15]. Soon Ae Chun et al. improve the classification process of crime hotspot detection. Naïve Bayes classifier was applied to the Cairo crime data set. They use a weighted estimate approach to find the probability of each crime. This approach facilitates the people and decision-maker to find out the criminal hotspots [16]. Sherif et. al incorporate the concept of a criminal environment in grid-based crime prediction modeling. RF, SVM, ANN, and KNN algorithms were applied. The experimental result demonstrates SVM achieved the highest accuracy 0.8811 amongst the others [17].

Cristina Kadar et al. employed averaging and boosting techniques from machine learning, to investigate the prediction performance on yearly different crime occurrences of New York City. The proposed system achieved absolute R2 metrics on a geographical out-of-sample test set is 65\% and on a temporal out-of-sample test set is 89% [18]. Alif Ridzuan Khairuddin et al. forecast the future crime using a hybrid DA-GTB model with an optimization algorithm called Dragonfly Algorithm (DA). For the optimization of Gradient Tree Boosting, three parameters are used: learning rate, the number of trees, and the size of individual trees. The experimental results show the application of DA for parameter optimization shows a positive impact in enhancing GTB forecasting performance and produce a low error as compared to non-DA-GTB [19].

Priyanka Das et al. analyze the crime trend of kidnapping, murder, rape, and dowry death in Indian states. They use decision tree, KNN, RF naïve bayes, and Adaboost. Among other classifiers, the decision tree has a low misclassified rate for all crime types [20]. Irina Matijosaitiene et al. identified the urban areas where the top three most committed crimes could happen every hour of a day in Manhattan state. They apply KNN, RF, LR, and naïve Bayes on crime data set which contain crime type, location, date, and time. The experimental results Logistics regression performance accuracy is 0.79 on Larceny, 0.83 on harassment, and Assault 0.82. Logistic regression performs well among all classifiers [21].

Allemar Jhone et al. forecast the index (crimes refer to crimes against person and crimes against property) and non-index (are violations of special laws such as illegal logging or local ordinances) crime from 2018 to 2022 on the base of 2013 to 2017 crime data in a certain state of Surgio De Norte using K mean clustering algorithm.

The author made a cluster of identical traits and values. Each cluster gave the result and forecast the future trend of a specific crime in some specific area. Crimes like physical injury, homicide, violation of special laws, car napping, and other non-index crimes had increased to 26%, 25%, 25%, 24%, and 23% respectively for the year 2018-2022[22].

Aarthi et al. addressed the problem of hot spot detection. In this article, the K Mean clustering technique was used. In this work, he made a cluster based on identical traits and values. The streaming algorithm is used for the large amount of data that are added in live that's how enforcement agencies can access and predict the most dangerous of illegal activities [23].

Omkar Vaidy et al. predict the region that has high crime occurring probability and indicated the high crime-prone areas. The author compares the performance of fuzzy c means clustering, k means clustering, Hierarchical Clustering, and Self Organizing Map. K Mean and Fuzzy C Mean clustering provide insight that lets the officers track criminal activities, predicts the likelihood of incidents, effectively deploys the resources, and solves the cases faster in an efficient way [24].
M. Premasundari et al. addressed the problem of crime rate analysis. They use the Fuzzy C-Means clustering model. Crime US-Arrests dataset was used for model evaluation. The experimental results predict the high possibility of crime incidence occurring. This dataset consisted of 3 clusters: namely Murder, Assault, and Rape [25].

Vineet et al. predict the place that has a high probability for crime occurrence using the K means algorithm. The clustered results were used to identify high crime-prone areas and to design precaution methods for the future [26].

Machine Learning
According to Arthur Samuel (1959), "Machine learning is the field of study that gives computers the ability to learn without being explicitly programmed". In traditional programming, we give data and programs as input to a computer, and it generates output but in machine learning, we give data and output to a computer, and it gives the program. According to Tom Mitchell (1998) "Machine Learning is the study of algorithms that improves their performance P, at some task T with experience E".

For any machine learning algorithm, adaptivity is a must, if an algorithm is adaptive, we call it a learning algorithm. Machine learning algorithms learn from data. The main task of a machine learning algorithm is to improve the performance with experience. The main type of learning includes supervised learning, unsupervised learning, semi-supervised learning, and reinforcement learning.

Supervised Learning
In supervised learning, we give training data and desired class label (output label). Target variable can be continuous or discrete. Supervised learning has 2 types which are regression and classification.

Classification
Classification is a supervised learning type in which predicts categorical features. Classification algorithms are used to classify class labels which can be binary or multiclass. Some classification algorithms are Adaboost, decision tree, neural network, logistic regression, and multilayer perceptron.

Regression
Regression is a supervised learning type in which we predict the continuous value of the class label. There are various regression analysis algorithms among those linear regression is most widely used. In simple linear regression, we predict the dependent variable based on one independent variable. In Multiple linear regressions, we predict dependent variables based on many independent variables.

Unsupervised Learning
In unsupervised learning, we find the hidden pattern based on similarity. We make a segment or group of data based on similarity. In unsupervised learning, we give training data without a class label.

Propose Methodology for Crime Analysis and Prediction
This section has 4 parts. Firstly, data has been extracted from the website. After this, data preprocessing is applied to the data set. Then Machine Learning techniques are used to perform crime analysis. Finally, results are evaluated using numbers of parameters such as MSE, r square, etc. Figure 3 shows the working flow of the methodology. The first and second steps collect data and perform preprocessing. In the third and fourth steps, a machine learning algorithm has been applied to evaluate parameters.

Python is the most powerful and flexible language which is most widely used in data science. Anaconda package has a powerful spyder tool that has also been used in data science. This work has been done in the Spyder tool using Python language. Sklearn preprocessing library has been used for data preprocessing. Sklearn Model-selection library has been used for modeling the algorithm. Sklearn metrics library has been used for the evaluation of the model.

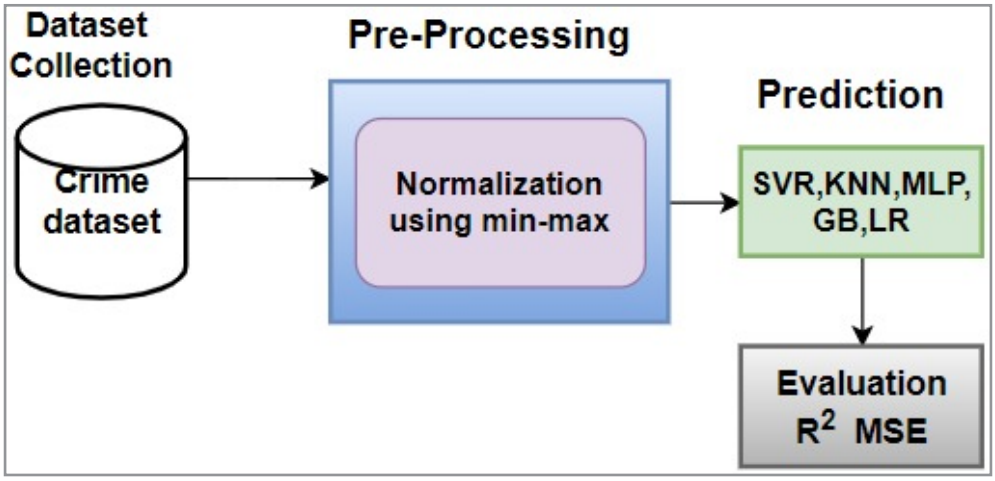

Figure 1: Methodology Diagram for Crime Analysis and prediction

Data Set

The crime data set has been extracted from the https://data.world/government website. This data set has 10 attributes which are state name, state total population, Property crime total, Murder, and non-negligent Manslaughter, Aggravated assault, Forcible rape, Robbery, Burglary, Larceny-theft, and Motor vehicle theft. This data set has yearly wise total population of the USA and a total number of crimes of different crime types from 1960 to 2102. The data set of social and economic indicators are also extracted from https://data.world/government.

This data set has 6 attributes: poverty level, literacy rate, and unemployment, the total population of states, regions, and median annual income per person. After data collection, we combine two data sets.

Another data set of USA economic factors is collected from https://databank.worldbank.org. This data set contains, GDP, GDP Per capita, imports, exports, urban growth, unemployment, and inflation from 1960 to 2012. In this data set robbery, property crime total, burglary, motor vehicle thefts are treated as dependent whereas poverty level and unemployment rates are treated as independent variables. The collected data is clean before applying the machine learning technique. In the next section, we are going to discuss data preprocessing.

Data Preprocessing

In this part, we handle missing values and normalized the data set. For imputing missing values, we replace missing values by taking an average of all values of that feature. The scale of dependent and independent variables is of different ranges. For normalizing the features, we apply the min-max normalization technique. In the min-max technique, we subtract the value from min and divide it by min minus max.

$$Xnew = (Xold-Xmin)/(Xmin-Xmax) \quad \text{Eq.(1)}$$

Where Xold is a vectorized feature, Xmin and Xmax is the minimum and maximum value of that feature.

Machine Learning Model for Crime Prediction

For analysis of crime data set, we apply support vector machine, gradient boosting, Multilayer perceptron, K Nearest Neighbor, and linear regression.

Linear Regression

Using linear regression, we predict continuous output variables by making linear hypotheses function. There can be one or more input variables and one output variable. In linear regression, data have a linear relation between them, and we separate it by using a straight line. In simple linear regression, we have one input and one output variable, but in multivariable linear regression, we have more than one input variable and one output variable. The equation of linear regression is written down in Eq.2.

In simple linear regression, a dependent variable X can be modeled as a linear function of independent variable Y using Eq.2

$$Y=a+bX \quad \text{Eq.2}$$

Y is a dependent variable. a and b are the parameters of the model. In this model a is called as intercept and b is slope and X is an independent variable.

Support Vector Regression

Support Vector Regression is a model used for regression problems and it's used the same principles as SVM for classification. SVR solves a linear and non-linear problem. C and Gamma are the parameters of SVM. The value of C controls the tradeoff between smooth decision boundary and classifying training points correctly. The value Gamma determines that how far the influence of a single training example reaches. We train this model at C=200 and gamma=0.01 with the RBF kernel.

Multi-layer Perceptron

Perceptron is the basic building block of a neural network. In a simple perceptron model, we set initial weights, and multiply these weights to input and pass it to the activation function (such as logistic, relu, tanh, identity) to produce an output. We train weights by using an optimizer to learn from data. In multilayer

perceptron, we input layer, hidden layer, and output layer. We used hidden layers to solve a complex problem (Non-linear). In each hidden layer, we have neurons. Each neuron receives inputs multiply them with some weights and pass them to an activation function. Out of each neuron at the hidden layer is the input of the next layer's neuron. A neural network algorithm can be used for both classification and regression problems. We train this model with 3 hidden layers. ReLu activation function is used to identify the patterns.

K Nearest Neighbor

K-Nearest Neighbor is a supervised learning algorithm that can be used in classification and regression problems. KNN is a non-parametric model, not make any assumptions on the data. KNN assumes that similar things are near to each other and in proximity. KNN computes the distance between the new data points and every training data point. The model picks K entries in the database which are closest to the new data point. In regression, it takes an average of k neighbor to produce the output. We train this model at k=3.

Gradient Boosting

Gradient boosting is an ensemble learning algorithm that combines many weak learners to create a strong model. It can be used in classification and regression problems. Gradient Boosting first calculates the average of the target variable and then calculates the residual error. After this build a decision tree and predict the target variable using all trees. Residual is again calculated, and this process is continuing until the termination condition meets. n_ estimators' parameter is used to define the number of trees, learning_ rate is controlling the convergence speed of the algorithm, max_ features is used to set the number of splits, max_ depth is used to define the depth of the tree. This model trains at n_ estimators 20, learning_ rate 0.01, max_ features 2, and max_ depth 2 parameter value.

Evaluation Metrics for Crime Prediction

We evaluate the performance of our proposed method for crime prediction using MSE, and Coefficient of determination.

Mean Square Error

The MSE is calculated to measure how the predicted value is nearest to the actual value. The formula is written down in Eq.3.

$$1/m\sum(y\text{-}ypred) \qquad \text{Eq.3}$$

Where y is an actual value and ypred is a predicted value

Coefficient of Determination

R Square is a measurement parameter that represents the proportion of variance for the target variable which is explained by predictor variables. R squared tells us how our model is fit on the data. R squared always ranges from 0 to 1. R is calculated by using Eq.4.

$$R2 = 1\text{-}unexplainedvariation/Totalvariation \qquad \text{Eq.4}$$

Results and Discussion

Support Vector Regression, Multilayer Perceptron, KNN, and Gradient tree boosting have been applied to crime data to perform analysis. In the First experiment burglary, robbery, property crime, and motor vehicle snatch are considered as target attributes and numbers below the poverty level line, and unemployment rates are treated as an independent variable. Support Vector Regression and Linear regression algorithms have been applied on each crime type, unemployment, and number below the poverty level line.

In a second experiment, we consider the total crime rate of the USA as the target variable and GDP, GDP Per capita, imports, exports, urban growth, unemployment, and inflation as an independent variable. MSE and R Square have been calculated in all cases. The experimental results of the first experiment show that unemployment most affects robbery crime. The second experiment concludes that the GDP of a country, GDP Per capita, imports, exports, urban growth, unemployment, and inflation also impact the total crime in the country.

Table 1: Robbery as target variable and unemployment as an independent variable

Algorithm	MSE	R Square
SVR	0.22	0.92
LR	0.0.1	0.93

Table 1 shows the values of MSE and R Square of robbery and unemployment. Linear regression has low MSE, and high R square as compared to SVR.

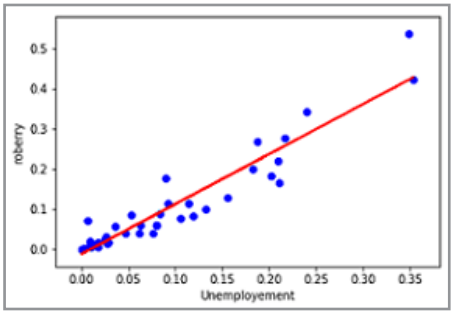

Figure 2: Prediction graph of unemployment and robbery

In Fig.2 we plot the predicted and observed value of unemployment and robbery. Unemployment is considered as an independent variable and robbery is considered as a dependent variable.

Table 2: property crime as target variable and unemployment as an independent variable

Algorithm	MSE	R Square
SVR	0.39	-0.03
LR	0.05	0.38

Table5 shows the values of MSE and R Square of property crime and unemployment. Linear regression has low MSE, and high R Square as compared to SVR.

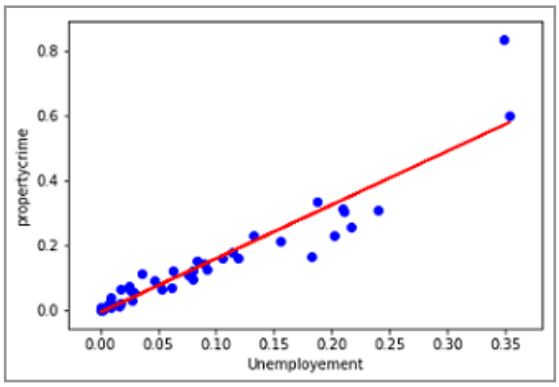

Figure 3: Prediction graph of unemployment and property crime

In Fig.3 we plot the predicted and observed value of unemployment and robbery. Unemployment is considered as an independent variable and property crime is considered as a dependent variable.

Table 3: Burglary as target variable and unemployment as an independent variable

Algorithm	MSE	R Square
SVR	O.33	0.25
LR	0.05	0.30

Table 3 shows the values of MSE and R Square of burglary and unemployment. Linear regression has low MSE, and high R Square as compared to SVR.

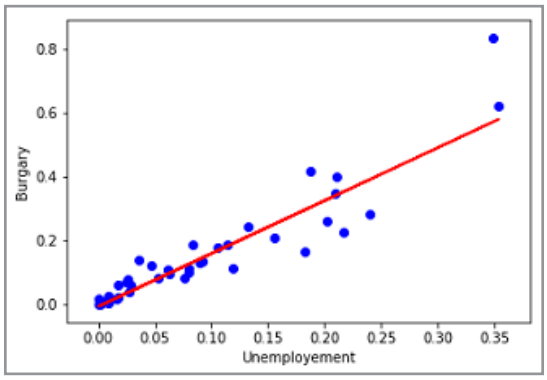

Figure 4: Prediction graph of unemployment and burglary

In Fig. 4 we plot the predicted and observed value of unemployment and burglary. Unemployment is considered as an independent variable and burglary is considered as a dependent variable.

Table 4: motor-vehicle-snatch as target variable and unemployment as an independent variable

Algorithm	MSE	R Square
SVR	0.13	0.88
LR	0.01	0.87

Table7 shows the values of MSE and R square of motor-vehicle-snatch and unemployment. Linear regression has low MSE and SVR has high R Square.

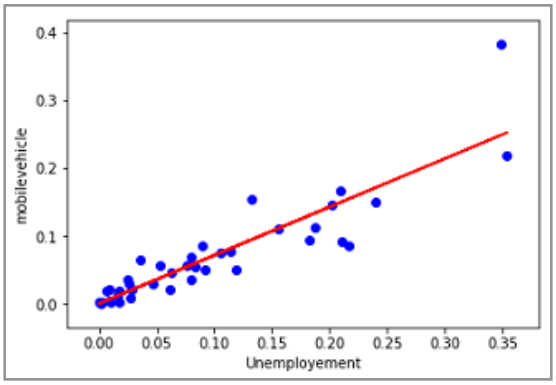

Figure 5: Prediction graph of unemployment and motor vehicle snatch

In Fig.5 we plot the predicted and observed value of unemployment and motor vehicle snatch. Unemployment is considered as an independent variable and motor vehicle snatch is considered as a dependent variable.

Table 5: Robbery as target variable and Number below poverty line as independent variable

Algorithm	MSE	R Square
SVR	0.13	0.88
LR	0.01	0.87

Table 5 shows the values of MSE and R Square of property crime and No below the poverty line. Linear regression has low MSE, and high R Square as compared to SVR.

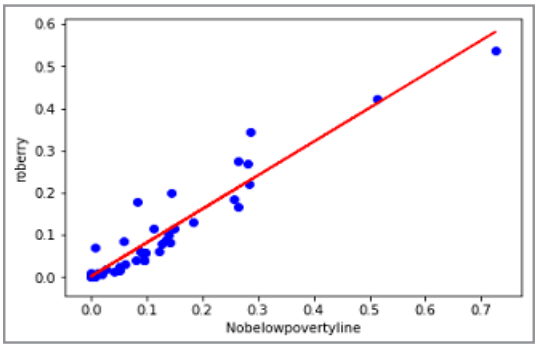

Figure 6: Prediction graph of No below the poverty line and robbery

In Fig. 5 we plot the predicted and the observed value of No below poverty line and robbery. No below the poverty line is considered an independent variable and robbery is considered as a dependent variable.

Table 6: Property crime as target variable and No below the poverty line as an independent variable

Algorithm	MSE	R Square
SVR	0.15	0.92
LR	0.01	0.90

Table 6 shows the values MSE and R Square of property crime and No below the poverty line. Linear regression has low MSE and SVR has high R Square.

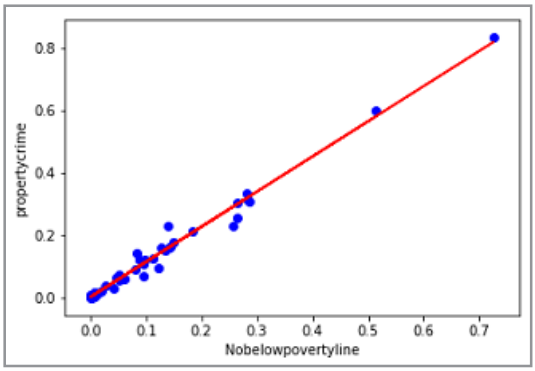

Figure 7: Prediction graph of No below the poverty line and Property Crime

In Fig.7 we plot the predicted and the observed value of No below the poverty line and property crime. No below the poverty line is considered as an independent variable and property crime is considered as a dependent variable.

Table 7: Burglary as target variable and No below the poverty line as an independent variable

Algorithm	MSE	R Square
SVR	0.15	0.92
LR	0.01	0.90

Table 7 shows the values of MSE and R Square of Burglary and No below the poverty line. Linear regression has low MSE and SVR has high R Square.

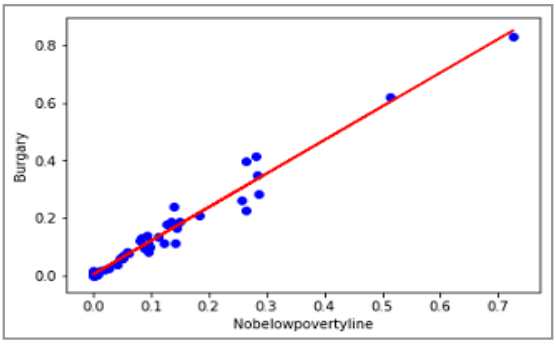

Figure 8: Prediction graph of No below the poverty line and Burglary

In Fig.8 we plot the predicted and the observed value of No below poverty line and Burglary. No below the poverty line is considered an independent variable and Burglary is considered as a dependent variable.

Table 8: Motor-vehicle-snatch as target variable and No below the poverty line as an independent variable

Algorithm	MSE	R Square
SVR	0.17	0.66
LR	0.03	0.65

Table 8 shows the values of MSE and R Square of mobile-vehicle snatch and No below the poverty line. Linear regression has low MSE and SVR has high R Square.

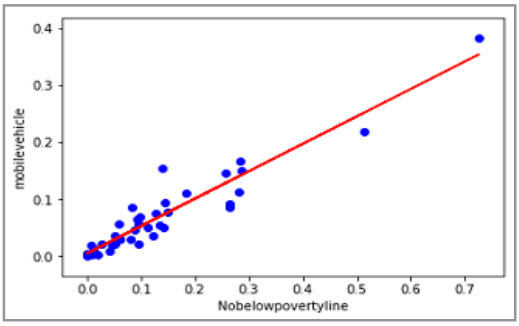

Figure 9: Prediction graph of No below the poverty line and Motor vehicle snatch

In Fig.9 we plot the predicted and the observed value of No below the poverty line and Motor vehicle snatch. No below the poverty line is considered as an independent variable and Motor vehicle snatch is considered as a dependent variable

Table 9: Performance Measurement of Second experiment

Algorithm	MSE	R Square
SVR	0.01	0.94
GB	0.011	0.95
MLP	0.001	0.98
KNN	0.011	0.96

Table 9 shows the mean square error, absolute mean error, and r square. From the experimental result, it is observed that Multilayer perceptron performs well as compared to SVR, GB, MLP, and KNN. Multilayer perceptron has high r square value (0.98) as compared to SVR (0.94), GB (0.95) and KNN (0.96). Our all-proposed approach has a minimum error near zero.

Conclusion

Crime analysis is very helpful for understanding the factors that influence the crime rate. In the last few years, it has been observed that in crime analysis "machine learning techniques" give a better result. In this work, machine learning algorithms have been applied to crime data to identify the factors which affect the crime rate in the United States of America. In the first experiment Support vector regression and linear regression have been applied to crime data of 50 USA states. The performance of both models has been calculated and observed.

It is concluded that linear regression has the highest r squared and low mean squared error. In the second experiment performance of SVR, GB, MLP, and KNN are evaluated using R square and MSE. It is observed that unemployment most affects the crime rate. To reduce crime, it is important to overcome the problem of unemployment. In the future, the impact of other factors such as literacy rate will discuss on child rape and murder. The machine learning classifier such as Random Forest will also use to perform crime analysis.

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