ANN based approach to predict criminal trends in Bangladesh

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***Abstract*—Crime trend analysis has become a mandatory task as the scale of crime is increasing rapidly all over the globe. In recent years, Bangladesh has encountered various types of crimes and the rate is increasing with its increased population. Both physical and digital based crimes have become very common and their fatality can disrupt the advancement of any country. To tackle the situation, it is important to investigate and forecast the crime patterns that can assist the law enforcement agencies for easier investigation. Machine Learning and Deep Learning based crime analysis has become very popular as they can accurately and efficiently analyze large criminal dataset. In this study, the authors implemented machine learning techniques as well as ANN architecture to assess and forecast crime trends in Bangladesh. The dataset in this experiment was collected from the Bangladesh Police website that consists of criminal records of various crimes during the years 2010 to 2019. Authors evaluated the performance of ANN with other regression models named linear Regression and Support Vector Regression for crime prediction. The proposed model(ANN) outperforms other two models in this study compared to all the performance evaluation metrics. Hence ANN model is suggested by the authors to forecast and analyze future crime trends.**

***Index Terms*—ANN, Crime Prediction, Logistic Regression, Support Vector Regression.**

I. Introduction

Crime trends seem to be increasing at an alarming rate in a developing country like Bangladesh. Over the years both cyber and physical crimes have increased drastically all over the world. Criminal activities affect not only the individual, as well as the community, society, or state. Even though the specific reasons for the increase in crimes are not clear but recent researches have shown that lack of education, poverty, unemployment seem to be prime factors for the rising crime trends [1]. It is disrupting life quality as well as economic growth in society [1]. Crimes like dacoity, murder, theft, women and child oppression have become very common these days. Bangladesh being a densely populated country in South Asia with ethnic diversity and multicultural rural and urban cities encounters small or big crimes every day. Hence to tackle or evade these crime trends it has become necessary to predict and investigate the crimes that are most likely to occur. Crime prediction can be done through proper data mining and statistical analysis [2]. Proper crime prediction analysis can aid the Police department and other law enforcement of Bangladesh to investigate and predict future crimes that will allow them to prevent and solve crimes in the future [2]. Over the years crime prediction approach using machine learning increased drastically [3]. Due to its capability of making decisions without human interventions, Machine learning models are now extensively used in forecasting and classification problems. Law enforcement agencies all over the world now use crime prediction methods for proper investigation. Using artificial intelligence and machine learning in this field can make their task easier. The majority of machine-learning-based crime analysis entails data gathering, classification, data visualization, pattern recognition, and prediction [1]. In this research, the authors implemented some prominent machine learning methods like support vector regression, Artificial Neural Network and linear regression on the criminal dataset of Bangladesh. These techniques were applied to all individual crime categories namely Dacoity, Robbery, Murder, Speedy Trial, Woman & Child Abuse, Kidnapping, Police Assault, Burglary, Theft. Authors found that ANN performed better than linear regression and support vector regression in terms of all performance evaluation metrics. For performance evaluation of these models the average in R^2 score, Mean Absolute Score(MAE) and Explained Variance Score(EVS) were recorded for each model. The best scores were found in ANN architecture for all three evaluation metrics. The remaining sections are structured as:

- Section II contains related works.
- Section III discusses the dataset, methods, machine learning techniques, and evaluation metrics.
- Section IV represents the experiment results and its discussion.
- Section V represents the conclusion of our experiment.

II. Related Works

Over the years several types of research have been conducted to predict and investigate crime trends using multiple statistical analysis as well as deploying machine learning algorithms. This approach actively helped law enforcement agencies in many countries of the world to predict and evade criminal activities.

In the paper [1], the authors implemented some machine learning predictive models to predict crimes in Vancouver

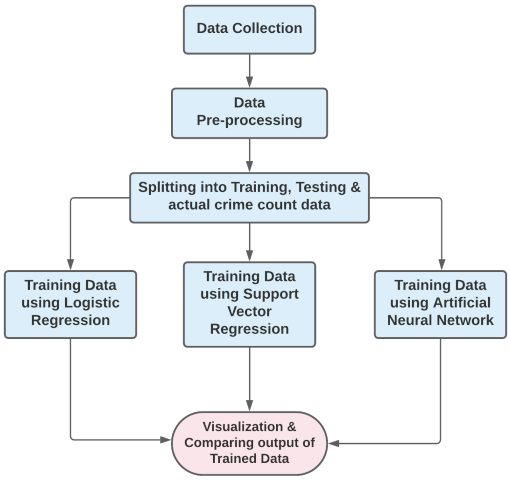

Fig. 1. Work Flow Diagram of the Prediction Model

using 15 years of crime data. They approached with two types of data processing method and finally applied K-Nearest Neighbour(KNN) as well as boosted Decision Tree to acquire crime prediction accuracy. The accuracy range was between 39% to 44%. In the paper [2] Linear Regression model was optimized and utilized for predicting future crime trends in Bangladesh. The dataset comprised of crime data of various categories such as robbery, murder, kidnapping, theft, etc. that occurred in different regions in Bangladesh in the past. It was demonstrated that criminal trends increase in Bangladesh with increased population growth. In work [4] authors forecasted crime trends using crime datasets of Portland and Chicago. The data was trained using complex neural networks also adding variations suitable to the temporal and spatial aspects of this problem. The authors proposed RNN+CNN model to forecast the crime trends which gave an accuracy of 75.6% in the Chicago crime dataset and about 65.3% in the Portland dataset. In [5] authors tried predicting the crime reoccurrence of an individual in reference to their criminal charge history. To tackle this problem authors build a prediction model using fully connected convolution layers for multi-label classification. Their dynamic window-based model achieved 99.7% accuracy compared to other models used in the experiment to predict the reoccurrence of a crime by a person. In the work [6] authors initially performed an exploratory data analysis on crime datasets to visualize the crime trends. Later several data mining and deep learning techniques were used on the dataset. Authors used the criminal dataset of Chicago, San Francisco, and Philadelphia in this experiment. Prophet model and LSTM gave comparatively more accurate predictive results compared to neural network model in this experiment. Authors in [7] used Deep Reinforcement Learning (DRL) techniques to analyze the performance of Criminal Network Analysis (CNA). Their proposed model, GPU-based DRL-CNA model was compared with the performance of some classical ML models namely Support Vector Machine, Random Forest and Gradient boosting Machine. The DRL-CNA model achieved 7.4% better performance than the second-best performing model which is Random Forest in this experiment. A spatiotemporal CNN was proposed in [8] to establish the relationship between crime and space-time to predict crime concentration in a certain geographical region and time. The proposed STCN (Spatiotemporal Crime Network) used the felony and the 311 data set from New York. The STCN obtained 88 percent and 92 percent accuracy in the felony and the 311 dataset respectively, performing better than other baseline models. In [9] crime prediction and crime, analysis was performed by using Random Forest and YOLO object detection model. The model used crime data from Indore city in India to classify and detect crime in a certain region or image. The model achieved 75 percent accuracy and is considered adequate for crime hotspot detections in the city.

III. Methodology

In this research, the authors implemented some widely used Machine Learning algorithms on the criminal dataset of Bangladesh. Three extensively used techniques namely Support Vector Regression, Artificial Neural Networks and linear Regression are implemented on crime dataset to predict the number of crimes in Bangladesh. The workflow diagram of this study is illustrated in Fig-1.

A. Dataset

In this work, the authors collected the real crime dataset of Bangladesh from Bangladesh Police's website [10]–[13] for conducting their research. The dataset consists of aggregated counts of several crimes that occurred in different regions of Bangladesh from 2010 to 2019 as classified by the police department of Bangladesh. The noteworthy offenses mentioned in the dataset are Arms Act, Robbery, Dacoity, Speedy Trial, Murder , Woman Child Repression, Kidnapping, Police Assault etc. The authors split the dataset in 90:10 ratio, where 90% of the dataset was implemented for training purposes and the remaining 10% used for testing.

B. Data Pre-Processing

Data Pre-processing is an important process to get intuitive and readable data for fitting them in machine learning models [14]. In this study, the missing data, imbalanced label, and data having less correlation were adjusted prior to building the predictive model. Then the columns for labels and input were separated for each crime and the data was normalized using a StandardScaler to facilitate faster convergence and thus, better training. Finally, after pre-processing we deployed them into machine learning models.

C. Linear Regression

Linear Regression is a commonly used Machine Learning technique for predicting and determining the cause and effect relationship between variables. The algorithm is appreciated by the researchers due to its simplicity and clear explanation of how the output is affected by input [2]. A linear relation is predicted between an independent variable generally denoted by x and a dependent variable generally denoted by y [15].

TABLE I
COMMON SVR KERNEL FUNCTIONS

Kernel	Function
Linear	$x * y$
Polynomial	$[x * x_i + 1]^d$
Radial Basis Function(RBF)	$exp\left\{-\gamma \left\|x - x_i\right\|^2\right\}$

For m training set with variables (x_1, y_1), (x_2, y_2), $(x_3, y_3)...(x_n, y_n)$, where (x_i, y_i) are elements of X and Y respectively, the linear equation of hypothesis function can be expressed as:

$$h_\Theta(x) = \Theta_0 + \Theta_1 x + ...\Theta_n \tag{1}$$

Here Θ_0, Θ_1... Θ_n refers to the regression parameters. These parameters are determined using a cost function:

$$J(\Theta_0, \Theta_1 ... \Theta_n) = \frac{1}{2m} \sum_{i=1}^{m} \left(h_\Theta(x^i) - (y^i)\right)^2 \tag{2}$$

Linear regression aims to reduce this cost function for all the training samples by calculating the values of Θ_0, Θ_1... Θ_n in such a way that $h_\Theta(x)$ remains close to y [2]. Using this method the best fitted regression line is generated which then allows us to forecast the variable which is in target for the given input.

D. Support Vector Regression(SVR)

SVR, a supervised machine learning technique utilized for regression analysis and classification. SVR is mainly built based on the concept of Support Vector Machine(SVM). For any complex sample data denoted by the equation: $G = \{(x_i, y_i)\}(N_{i=1})$. The input datas are basically independent variables and the output data are dependent variable [16]. SVR function is expressed as :

$$f(x) = \sum_{i=1}^{D} w_i \Phi_i(x) + b \tag{3}$$

Here,$f(x)$ refers to the forecasting values, w_i is the dimensional weight factor and $\Phi_i(x)$ denotes the map function. The adjustable factor is denoted by b. We can calculate the minimum coefficient of the dimensional weight factor using the equation:

$$R[w] = \frac{1}{N} \sum_{i=1}^{N} \left|f(x_i) - y_i\right|_e + \lambda \|w\|^2 \tag{4}$$

λ refers to standardization constant and we can express the term by the following equation:

$$\left[\left|f(x_i) - y_i\right|_e = \begin{cases} \left|f(x_i) - y_i\right| - \epsilon \left|f(x_i) - y_i\right| \geq \epsilon \\ 0, otherwise \end{cases}\right. \tag{5}$$

The common kernel functions in SVR are namely Linear, Polynomial and Radial Basis Function(RBF) respectively [17] as shown in Table-I.

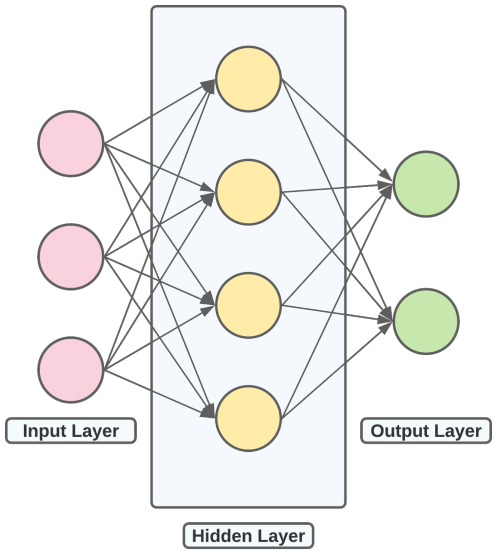

Fig. 2. Primary layers of an Artificial Neural Network

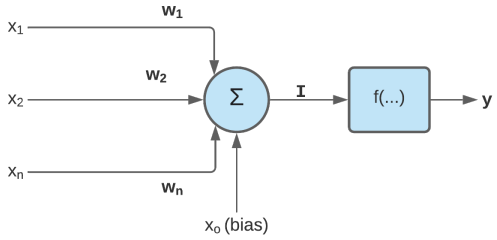

Fig. 3. Diagrammatic representation of a single ANN neuron

E. Artificial Neural Network(ANN)

ANN are mathematical, graphical network models designed to replicate the internal structure and function of the human brain and the nervous system to some extent [18]. Generally, a conventional ANN can be characterized as an interconnection of three kinds of mathematical layers, (i) Input Layer, (ii) Hidden Layer, and (iii) Output Layer [19] . Each fundamental unit in an ANN is termed as a neuron, analogous to a biological neuron. ANNs implement learning by near approximating the non-linear relationship between inputs provided and the corresponding training output. The end goal of the neural network is to reduce output

A typical neuron consists of an input, and its weight and bias values [20] as illustrated in Fig-3. The function used to convert this into a suitable output is called the activation function of the network. The inputs are multiplied with the weights and biases and then mapped by the activation function into an output. The general form of the equation of an activation

function [18] is given by:

$$f_{mip}(x) = \phi\left(\sum_{1}^{N_{on}} v_1 \phi\left(\sum w_{ij} x_l + b_{l0}\right) + b_0\right) \quad (6)$$

Here, the activation function is denoted by ϕ, v_1 and w_{ij} refers to the synaptic weights and biases are represented by b_{l0} and b_0

Besides the weights and biases in the neurons, there are certain parameters like learning rate, momentum, number of iterations, batch size, etc. that play an important role in setting the neural network to reach accurate results. ANN are widely used in facial recognition, natural language processing, and various image recognition tasks. It is also applied in financial forecasting, targeted marketing, fraud detection, and Intelligent searching of information. A special form of ANN, Generative Adversarial Networks (GAN) are used to perform various intelligent and complex tasks including speech generation, art generation, realistic photo generation, and 3D object generation.

F. Performance Evaluation Metrics

The performance evaluation metrics used for this research are R Squared score, Mean Absolute Error and Explained Variance Score . Authors calculated the metrics value for each of the models applied in this research.

1) R Squared score: R squared score can be explained as the ratio of total variance experienced by the model to the total variance. Higher value of R squared score implies that the variables are highly correlated, on the other hand, lower R squared value means the values are poorly correlated [15]. R^2 score to find the relation between true value and predicted value can be expressed by the equation:

$$R^2(y, \hat{y}) = \frac{1}{N} - \frac{\sum_{k=1}^{N}(y_k - \hat{y_k})^2}{\sum_{k=1}^{N}(y_k - \bar{y})^2} \quad (7)$$

Here the total number of samples is denoted by N, predicted value of the kth sample is denoted by $\hat{y_k}$ and corresponding true value is denoted by y_k . $\bar{y}$ is the average of all true values and can be expressed as: [=1$\frac{}{N\sum_{k=1}^{N} y_k}$

The R^2 score ranges from 0.0 to 1.0 where 1.0 denotes the best score and 0 denotes the worst score.

2) Mean Absolute Error(MAE): The average magnitude of error in a set of predictions can be calculated using Mean MAE. [2]. MAE is calculated using the formula:

$$(y, \hat{y}) = \frac{1}{N}\sum_{k=1}^{N}|y_k - \hat{y_k}| \quad (8)$$

Here, y= true value, $\hat{y}$ = predicted value
N = total number of samples
$\hat{y_k}$ = predicted value of the kth sample
y_k = corresponding true value

TABLE II
MODEL PERFORMANCE EVALUATION FOR DIFFERENT CRIME CATEGORIES

Crime Category	Algorithm	R^2 Score	MAE	EVS
Arms Act	LR	0.43	60.34	0.44
	SVR	0.51	47.39	0.54
	ANN	**0.90**	**23.97**	**0.90**
Dacoity	LR	0.97	5.59	0.97
	SVR	0.92	9.34	0.94
	ANN	**0.98**	**4.53**	**0.98**
Robbery	LR	0.96	9.61	0.96
	SVR	0.95	9.34	0.95
	ANN	**0.96**	**8.09**	**0.96**
Murder	LR	0.94	63.56	0.95
	SVR	0.86	86.69	0.88
	ANN	**0.97**	**34.46**	**0.97**
Speedy Trial	LR	0.94	23.06	0.94
	SVR	0.90	25.46	0.91
	ANN	**0.97**	**13.25**	**0.98**
Woman ,Child,Abuse	LR	0.94	23.06	0.94
	SVR	0.90	25.46	0.91
	ANN	**0.97**	**13.25**	**0.98**
Kidnapping	LR	0.96	6.98	0.97
	SVR	0.96	6.53	0.97
	ANN	**0.99**	**3.32**	**0.99**
Police Assault	LR	0.73	15.34	0.76
	SVR	0.83	8.66	0.83
	ANN	**0.87**	**9.07**	**0.87**
Burglary	LR	**0.99**	**15.31**	**0.99**
	SVR	0.98	16.37	0.98
	ANN	0.98	17.86	0.98
Theft	LR	0.96	80.72	0.96
	SVR	0.95	75.67	0.96
	ANN	**0.98**	**51.26**	**0.98**

TABLE III
OVERALL AVERAGE PERFORMANCE SCORES OF THE MODEL

Algorithms	Performance Metrics		
	R^2 Score	MAE	EVS
LR	0.882	30.357	0.888
SVR	0.876	31.019	0.887
ANN	0.957	17.896	0.959

3) Explained Variance Score(EVS): EVS can be defined as the ratio of variance of error to the true values [15]. It can be calculated mathematically using the following formula:

$$EVS(y, \hat{y}) = 1 - \frac{Var(y - \hat{y})}{Var(y)} \quad (9)$$

Here y and $\hat{y}$ refers to the true and predicted value respectively and the variance is denoted by Var. Higher the value of EVS, better the score and lower EVS value represents lower score.

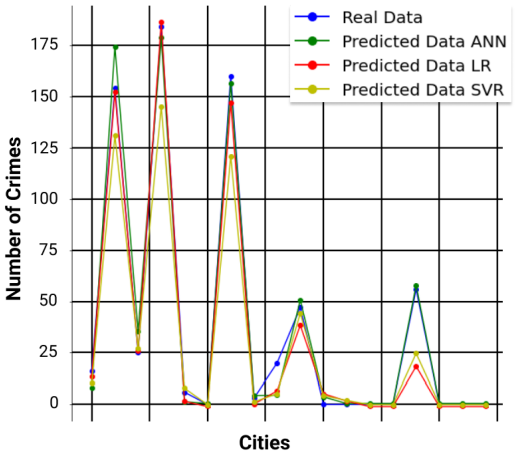

Fig. 4. Output for Dacoity on different prediction models

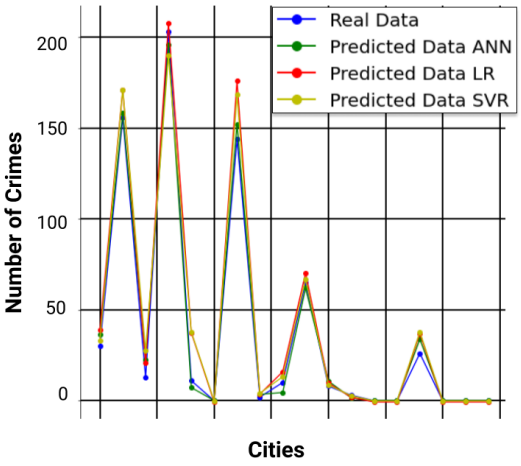

Fig. 5. Output for Kidnapping on different prediction models

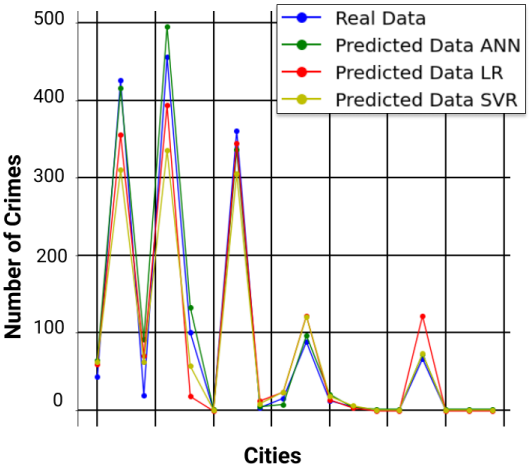

Fig. 6. Output for Speedy Trial on different prediction models

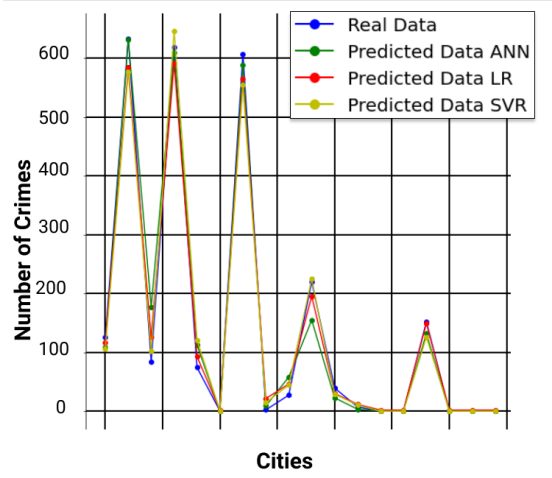

Fig. 7. Output for Burglary on different prediction models

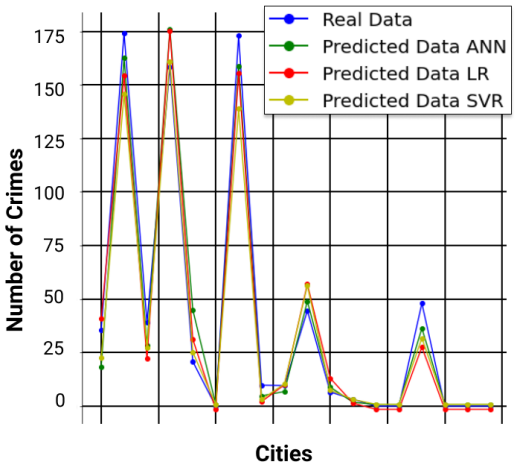

Fig. 8. Output for Theft on different prediction models

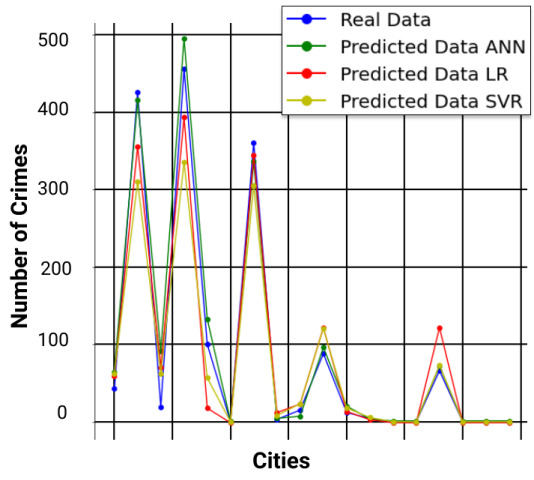

Fig. 9. Output for Women & Child Abuse on different prediction models

TABLE IV
A SUMMARY OF MOST RECENT WORKS FOR CRIME IDENTIFICATION USING MACHINE LEARNING MODELS

Authors	Year	Evaluation Metrics
[21]	2017	Accuracy = 83.39%, F1 - Score = 86.54%
[22]	2017	Accuracy=84.25% Precision=74.35% Recall= 80.55% AUC = 0.8333
[8]	2017	AUC =0.92, F1=0.88
[23]	2017	Accuracy = 94.25287%
[24]	2018	Accuracy=0.91, Recall=0.93, F1-score=0.92 Support=110
[15]	2019	EVS = 0.95, MAE = 28.32, R2 Score = 0.95
[25]	2020	Precision =0.98 Recall = 0.98 F1 Score = 0.98
Proposed by authors	2021	EVS = 0.959, MAE = 17.896, R2 Score = 0.957

IV. Experimental Results Discussion

In this study, the main goal is to investigate the performance of different machine learning algorithms for crime prediction in Bangladesh. For this purpose, the authors used the Criminal Dataset of Bangladesh(2010-2019). 90% of the dataset was utilized for training and remaining 10% for testing. For crime prediction, Logistic Regression, SVR and ANN have been applied in this study. The performance of these models was evaluated in terms of R2 score, MAE, and EVS. Table-II illustrates the model performance for each crime category. It has to be noted that, only the results for SVR using the "Linear" kernel is shown in Table II as the results of that kernel outperformed the other two kernels for the all the categories of crime discussed. The best scores for each algorithm are highlighted in the table for each category. It is visible that almost for all the crime categories the highest score rate were achieved for Artificial Neural Network(ANN). Our proposed model gives precise prediction for crimes like Kidnapping, Burglary, Theft, Dacoity. For other crimes also we got satisfactory results. The average performance of these models is shown in Table-III. We can see that the best average R^2 score is achieved for ANN which is 0.957 and the least score is for SVR which is 0.876. We observe that the average least mean absolute error is for ANN than the other two models which explains it's better performance. Finally the highest average EVS score is 0.959 achieved by ANN, whereas LR and SVR achieved 0.888 and 0.887 respectively. We can conclude that ANN outperformed the other two models in terms of all the evaluation metrics. Further comparison has been done between actual and predicted crime trends using the mentioned machine learning models for five significant crimes. These are illustrated using line graphs in Figure-4 to Figure-9 respectively. Table IV illustrates a summary of most recent works for crime identification using machine learning models comparing the proposed model. Overall ANN has the closest results to the actual values than the other two models for all the crimes. Hence taking all considerations and findings we suggest utilizing ANN for crime prediction.

V. Conclusion

With the rate of increase of crimes every day, it has become essential to predict the crime trends and patterns in Bangladesh. In this research, the authors utilized few machine learning techniques for predicting crime trends using the criminal dataset of Bangladesh. The main objective was to investigate the performance of each model applied in the dataset. The dataset was split into 90:10 ratio for training and testing using linear Regression, SVR and ANN respectively. After training and forecasting the dataset, performance metrics were evaluated for each crime category. All the performance metrics and comparative analysis of the implemented models have been shown in the paper. Results showed that the suggested methodology(ANN model) performed better than the other two models in terms of R^2 score, MAE, and EVS. Hence the authors suggest using Artificial Neural Network (ANN) for crime prediction to obtain precise crime trends. This study can be helpful for the Bangladesh Police and other law enforcement agencies to mitigate or evade further crimes in Bangladesh.

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