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Designing Time Series Crime Prediction Model using Long Short-Term Memory Recurrent Neural Network

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Abstract: Crime influences people in many ways. Prior studies have shown the relationship between time and crime incidence behavior. This research attempts to determine and examine the relationship between time, crime incidences types and locations by using one of the neural network models for time series data that is, Long Short-Term Memory network. The collected data is pre-processed, analyzed and tested using Long Short-Term Memory recurrent neural network model. R-square score is also used to test the accuracy. The study results show that applying Long Short-Term Memory Recurrent Neural Network (LSTM RNN) enables to come up with more accurate prediction about crime incidence occurrence with respect to time. Predicting crimes accurately helps to improve crime prevention and decision and advance the justice system.

Keywords: Crime Prediction, LSTM, RNN, Predictive Policing, Time-Series Prediction

I. INTRODUCTION

One of the main social problems in modern society is crime which is basically defined as an offence against public law. Since it is a main problem, crime has major effects on victims, the society and social institutions. Crime is a multi-faceted social problem because it involves personal responsibility as well as social, cultural and political aspects that contribute to it. Numerous studies have shown that different factors such as time of the day, weather, environmental characteristics, and past incidence of crime will make an influence in the future criminal activity. According to the current U.S. Department of State Travel Advisory at the date of this report's publication, Ethiopia has been assessed as level two exercise increased caution. Petty crimes occur at random in Addis Ababa. Criminal Violence in Addis Ababa and in southwestern and south-eastern Ethiopia has resulted in numerous injuries and deaths. Moreover, location of police resources can be viewed as another problem. It involves the total amount of police time required to perform tasks.

Demanding services on irregular time is one of the problem of police manpower assignment. Until recent years there were no modern tools and techniques employed to facilitate the handling and processing of records[1]. Some of the generalized statistical records that associate with crime are kept in a computerized way but the detailed data we need for our research is stored manually. The criminal records, which is used for this study, contains information about the type of crime committed by each criminal, specific date and time, and also specific place. Criminals are sent manually to the commission by filling the criminals profile form. Only the crimes that has given heavy weight will be recorded in the commission's criminal record list. Data mining turns out to be a stepping stone for predictive policing. By using data and data mining technologies, predictive policing has the potential to provide the best evaluation of what will happen. Researches have shown that data mining can greatly improve crime analysis and aid in reducing and preventing crime. Police districts in most of developed countries "prediction" has become the new watchword for innovative policing. Using predictive analytics, high-powered computers, and good old-fashioned intuition, police are adopting predictive policing strategies that promise the holy grail of to stop crime before it happens. This research incorporates a set of closely related crime events from both the immediate and longer-term past, with more recent crimes given a heavier weight in order to develop predictive model using LSTM recurrent neural network.

II. LITERATURE REVIEW

Researchers have devoted their attention on analyzing criminal activities mainly from place-centric perspectives. In the current literature, researchers have devoted their attention on analyzing criminal activities mainly from place-centric perspectives. Alexander Stec and Diego Klabjan take advantage of deep neural networks, including variations that are suited to the spatial and temporal aspects of the crime prediction problem. In order to address the temporal aspects of crime prediction, a Recurrent Neural Network (RNN) is used. For the spatial aspects of crime prediction, a Convolution Neural Network (CNN) is fitted [2].

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Mona Mowafy et al. (2018) proposed methods and techniques that can predict the crime type from unstructured text. The paper, focuses on how practically building an unstructured crime data prediction model using the scikit-learn Python Toolkit.

The main goal of the structured model is to predict the crime type, based on the unstructured data of the crime occurrence reports for improving the policeman decisions and lessen their investigation energies [3]. Getahun Tesemma (2017) focused on finding the nexus between urban poverty and property crimes which were committed in Addis Ababa city Ethiopia. Explanatory cross-sectional study was carried out in the ten sub-cities of Addis Ababa. Analysis was done using SPSS version 24. The findings characterize the offender respondents as poor and commission of property crime was their coping strategy for survival [4]. Adewale Opeoluwa Ogunde1 et al. (2017) applied classification rule mining method to develop a system for detecting crimes in universities. WEKA mining software along with the Iterative Dichotomiser 3 (ID3) decision tree algorithm is used to analyze and train the data. The model acquired was used to create a system that showed the unseen relationships among the crime-related data, in the form of decision trees. The developed system could effectively predict a list of possible suspects by simply analyzing data retrieved from the crime scene with already existing data in the database [5]. Ying-Lung Lin et al. (2018) proposed a model that establishes a range of spatial-temporal features by integrating the notation of a criminal environment in grid-based crime prediction modeling. The Deep Neural Networks model is used, which outperforms the popular Random Decision Forest, Support Vector Machine, and K-Near Neighbor algorithms. The F1-score increases about 7% on 100-by-100 grids. Experiments demonstrate the need for the geographic feature design for increasing performance and descriptive ability. Furthermore, testing for crime dislocation also shows that the model design outperforms the baseline [6].

III. METHODOLOGY

A general procedure for crime prediction using LSTM RNN can be divided into four steps, which will be presented here, and discussed in detail in the following sections.

A. Data collection

Large amount of data is collected from bole sub city police department, Addis Ababa, Ethiopia. Originally information's of the corresponding crime is recorded when the individual is caught by the police. In fact, all police men are provided with a centralized form or record format that should be filled when crime is committed or when the offender is caught. This record format holds crime records that are stored manually which are waiting to be entered in to automated system. Even though, large amount of data is needed to train a neural network algorithm, due to time constraint to enter the data, top 6033(six thousand thirty-three) records are taken for this research. We choose five crime types (Assault, Cheque Fraud, Violence, Drug, and Theft), that happened more frequently than other crime types from all crime types.

All the necessary libraries and packages are installed through Conda. Libraries and packages like: NumPy, Pandas, Matplotlib, Sckit-Learn, TensorFlow, keras. We imported Pandas NumPy and pandas to our Jupiter notebook and feed our csv data into pandas Data frame through the function called **read_csv**.Matplotlib library is used to plot 2D figures in a variety of formats. It makes it easy to visualize data cause a picture worth a thousand words. It's a very powerful plotting library useful for peoples using python and NumPy. Pyplot is the most used module of matplotlib. It provides an interface like MATLAB but instead it uses Python. Matplotlib figure can be categorized into four parts: Figure, Axes, Axis and Artist.

B. Data Preprocessing

Data preprocessing have significant impact on generalization performance of machine learning and data mining algorithm and it is transformation of raw data before feed into the machine learning and datamining algorithm[7, 8]. In the data pre-processing phase, we transform raw data into machine understandable format. Raw data are mostly incomplete: it lacks attribute values or attributes of interest, noisy: it contains errors and outliers, inconsistent: it contains discrepancies in codes.After importing libraries and the raw data, we check out for the missing values which is none and in the next step we change the categorical values. Label encoding provides very efficient tool for encoding labels of categorical data to numeric values. Then the numerical values are converted to float by using astype (float) method.

Minmax scaling is considered as a way to normalize data in which we scale each feature to a fixed range. It is probably the most famous scaling algorithm. In this scaling technique values will end up ranging from 0 to 1 by shifting and rescaling. This is done by subtracting the minimum value and dividing by the maximum value minus the minimum values [9]. When scaling the values between zeros to one, the categorical values that are changed to numeric values will also be scaled too. After normalizing the data, the data has to be transformed to be executed in the right order. Sckit-learn provides pipeline class to help with transformations. **Fit transform ()** joins **fit()** and then **transform()** on the same data and is used for initial fitting of parameters.

C. Split Data

We slice it into training set and test set by using **train_test_split**. We imported **train_test_split** from sub library model selection in order to split the data to train set and test set. It is important when doing time series to split train and test with respect to a certain date. So, we don't want the test data to come before training data. When splitting the data, we make sure that our test set is large enough to yield statistically meaningful results and it is a representative of the whole dataset. In splitting the data our goal is to create a model that generalizes well to new data. It's usually around 80/20 or 70/30 depending on the amount of data that we have. We used 80/20 train test split; 80 for train and 20 for test respectively.

This enables us to make a good evaluation of the model we used by measuring how well it simplifies on new data it has not yet seen. If the test set isn't well created, we won't be able to draw any meaningful decisions about our model [10].

D. Prediction Model Development

There are many types of LSTM networks that can be used for different types of problems. For this research, we used vanilla LSTM model. This LSTM model has a single hidden layer and an output layer which is used to predict. Input shape argument of first hidden layer specifies the input shape for each sample. The current hidden state $h(t)$ is generated from the previous hidden state$h(t-1)$.

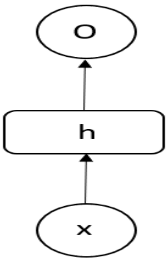

Figure 1: Vanilla LSTM

We predicted one-year data of crime type and location. To get clear pattern, we divide the time into month, day and hour. The graph below shows the monthly crime prediction.

IV. RESULT AND DISCUSSION

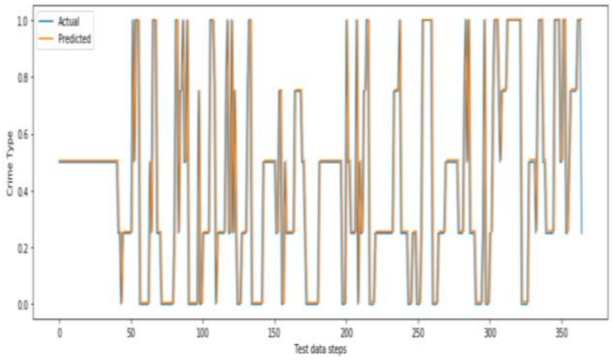

Figure 2A): Visualization of Data in monthly crime type prediction

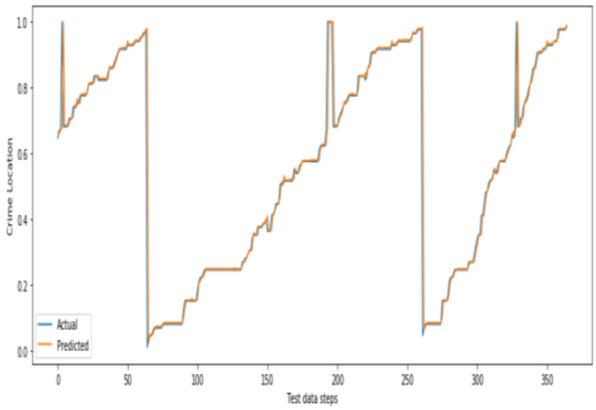

Figure 2B): Visualization of Data in monthly crime location prediction

In the above figure (Figure 2), the first graph (A) shows crime type prediction of the actual and predicted graph. We get an R-square score of 0.879 and MAE of 0.020. The second graph (B) shows the neighborhood prediction of the actual and predicted graph we get R-square score of 0.930 and MAE of 0.017. There happens to be 81 crime location in our data and each location will vary based on specific time step.

A. Results on daily distribution

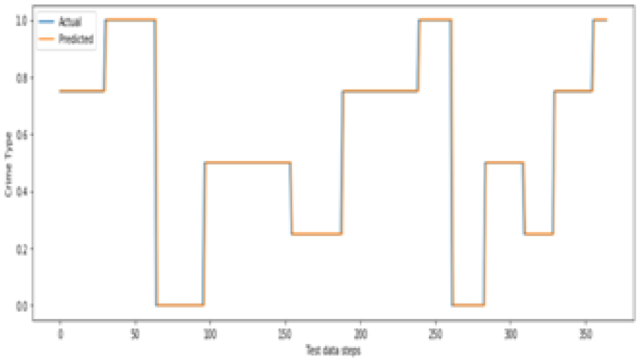

Figure 3A) Visualization of data in daily crime type prediction

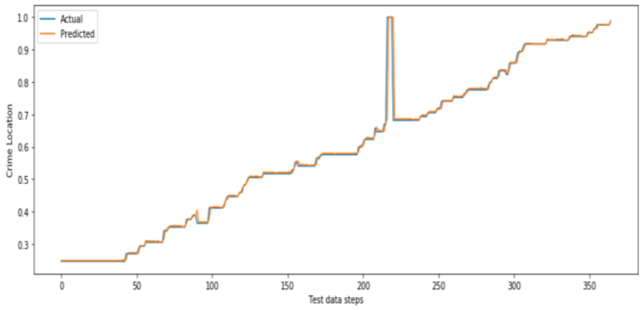

Figure 3B) Visualization of data in daily crime location prediction

In the first graph (Figure 3: A), which is the crime type prediction in a daily basis, the R-square is 0.925 and MAE is 0.005. Figure 3: B shows the daily crime location prediction. It shows the prediction quality of the test data. The R-square is 0.989 and the MAE is 0.015.

A. Results on hourly distribution

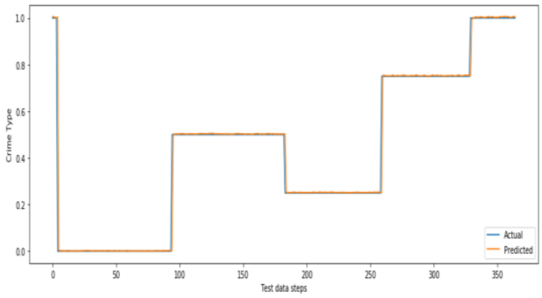

Figure 4A): Visualization of data in hourly crime type prediction

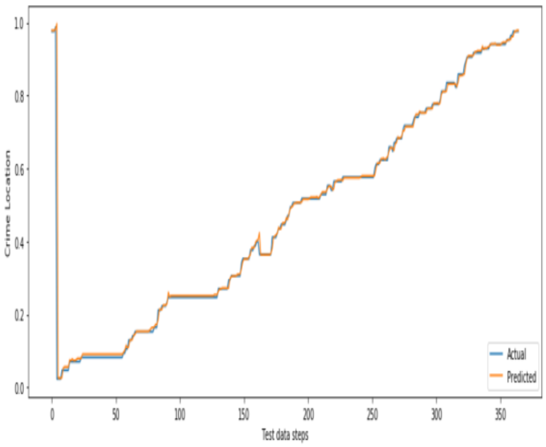

Figure 4B): Visualization of data in Hourly crime location prediction

We get an R-square score of 0.959 and MAE of 0.009 from figure 4: A. This hourly crime type prediction presents that there is almost a slight difference between crime types at each hour but as the result shown Figure 4: B, the location becomes dense as the time increases. The accuracy score is 0.968 and MAE is 0.007 which is closer to the actual value.

V. CONCLUSION

The method for this research incorporates past criminal activity records in bole sub city, Addis Ababa, Ethiopia, that models them based on RNN LSTM to predict occurrence of crimes. The research approach consists five phases. Firstly, we collected the crime data from bole sub city, Addis Ababa, Ethiopia police commission. Time series data is used to extract context information. We then undergo with the process of data pre-processing and generate more efficient data that can be used in predicting crime. Thirdly, LSTM RNN model is employed to accurately predict crime incidences. Then after, train dataset has undergone through data cleaning and data transformation process. Through experiments and analysis, we are able to determine that LSTM model gives high quality of prediction. R-square score is used to evaluate the model. The LSTM model has high prediction accuracy and the low error rate, showing best generalization capability. The pick points where crime can happen in a specific period of time were defined and conferred with respect to crime locations.

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