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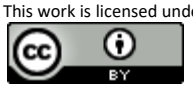

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A SURVEY OF BIG DATA AND DATA MINING TECHNIQUES FOR CRIME PREVENTION

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Abstract: Crimes remain a serious challenge to many societies and nations across the globe, despite technological advancement. Efforts by security agencies must remain a step ahead of potential attacks in order to effectively prevent crimes from occurring. The police stations and other related criminal justice departments have several large databases that can be used to forecast or examine criminal activities. Data Mining, the method of uncovering sensitive information from big data, is now an effective tool for combating, curbing and preventing crimes of all sorts. The main aim of this paper is to provide a systematic survey of how Data Mining techniques are applicable in combating crimes. In this paper, we selected widely applicable data mining techniques that were commonly used for crime analysis and prevention in previous related studies. A summary table of many relevant crime- Data Mining applications is included that will serve as a reference for researchers. Each technique has its specific use. Data mining methods are quickly explained to the reader that includes Classification, Cluster analysis, Association rue mining, Entity extraction and Social network analysis amongst others.

Keywords: Big Data, Crimes, Data Mining, Survey.

I. INTRODUCTION

Historically solving crimes was the obligation of professionals in criminology and police departments. Increasing the use of computerized systems to monitor crimes and identify offenders has led computer data researchers, to help to track crimes and trace criminals. Crime prevention and analysis has become an important factor in crime and a very difficult aspect in solving crimes. Several studies have found different techniques for solving crimes and other applications.

Majority of criminals never work in a vacuum but communicate with each other to carry out their illicit work. Worrisome though is the fact that there appears to be a degree of associative relationship among network members in most organized crime. From collecting messages, giving information, operation and, in most cases, connecting one network to another. Today, various security forces, police departments, and intelligence agencies such as the DSS and the JTF are actively gathering, analyzing data and investigating coordinated and individual crime to establish precautions to prevent future attacks [28].

Meanwhile, manual crime reporting and review system is no longer reliable and provides no security to prevent crime occurrence [36]. The amount of data produced, estimated at billions of connected devices, serves as useful sources to be utilized. Previously stored crime data from diverse sources tend to grow steadily. As a result, the management and analysis with massive data is very difficult and complex.

Given that, flow of information is now almost virtual reality and the update duration has been limited to fractions of a second. Meanwhile, as we live in the era of Big Data, the amount of digital data transmitted online is trillion times greater than the global population. Each of us currently has several zeta bytes of data from our own personal birth-to-death history, including addresses, phone

calls records, messages, emails broadcast on various social messaging apps, CCTV footage, financial transactions, etc. [34]. As such, the trending issue of insecurity, especially the increase in the frequency of crimes in Nigeria, cannot be untraced.

Apace with the rising use of the computerized systems to trail crimes, Computer data analysts have started to support law enforcement and police not only in speeding up the crime reduction process [26], but also to predict future crimes. The use of many Data Mining techniques is further impacted by the growing abundance of Big Data, and its ease of use for people who lack expertise in data analysis and statistical information [14]. Access to data plays an important role in the efficiency of data mining in crime, as reported by many authors, but problems arise because access is impeded by security issues [17].

There is an increasing need for modern and efficient methods for crime prevention. The transformation of 'Big Data' which requires narrative advances towards the adequate and precise analysis of the enlarging sizes of crime data has been a major threat for all police force and intelligence-coordinating events. It is in this scenery that Data Mining is described as a robust tool with high capacity to aid criminal investigators concentrate on the most essential of information concealed within the 'Big Data' on crime [37]. Data Mining as a weapon for crime investigation is identified as a similarly of late and highly sought area of research [8].

Data mining procedures engage different programming algorithms to extract concealed knowledge from large amount of data. Defense intelligence agencies of the mostly developed world have in recent years put great emphasis on data mining and its applications [11]. Data mining uses data analysis techniques to identify patterns and trends in crime. It can help solve crimes more quickly and help with detecting the crime.

This paper is aimed at providing a concise review of the data mining applications used for identifying and preventing crime over the years. It is expected that this informative review paper will be useful for introducing Data Mining techniques to crime researchers and investigators, in addition to supporting and encouraging future research into developing data mining techniques for crime analysis more especially in the African countries, and Nigeria to be precise. This is due to the given rise in crimes mostly in the northern part of the country. In order to enable such use, the survey has been organized so that interested parties could easily refer to this article alone to apprise themselves on research that has already been conducted, and the resulting outcomes which have been attained.

The main contribution of this paper can be viewed in two phases as it not only captures majority of the significant data mining techniques in crime by classifying these based on different types of techniques, but also presents an introduction into each of the relevant Data Mining techniques that have been used in analyzing crimes. In addition, the survey also includes in tabular format a summary of Data Mining applications in crime which can act as a quick reference guide for researcher.

II. DATA MINING TECHNIQUES USED IN CRIMES

A. Review Stage

Usually analyzing large sets of crime data is not an easy task for the police and other security agents. Data mining is the analytical tool used to analyze the historical data to find changes, patterns and theoretical frameworks to retrieve the hidden information. The crime data used for the analysis must be accurate and sufficient, and there must be Expert know-how and practice. The suspect can be examined on the basis of crime scene information that is evaluated against historical crime events and with data mining algorithms, the results are predicted.

Furthermore, the analysis can be used to predict crimes in advance or by deploying resources to the targeted areas found by the method. This method or system will help in ensuring peace around and curtail crimes in the targeted areas. We have different data mining techniques in predicting hotspots of crimes and to make accurate decisions. The criminals may have certain characteristics, and some may differ from one crime to another. Such information can be taken as input dataset. The input dataset is issued to a preprocessor that performs the preprocessing according to the requirements. Once the pre-processing has been done, the characteristics are derived from that information that may be in the form of text information from emails, day-to-day crime variables, criminal features, location of the criminal, etc.

The pre-processed result is additionally given to the data mining algorithm used based on the requirements. The requirements can be anything from identifying the crime prone areas to predicting the suspect based on earlier crime records. The latest techniques, compared to traditional data mining techniques, rely on both structured and unstructured data to detect patterns in order to control and reduce the rate of crimes [2]. There are many data mining techniques used for crime prevention but the commonly used are: Clustering, classification, Association rule mining, Entity Extraction and social network analysis. Table 1 is offered as a guide to provide a clear understanding of the Data Mining applications in crime. This table summarizes information based on the data mining methodology used and provides information about the data sets used, objectives of the research and the key techniques of each method.

TABLE 1: OVERVIEW OF DATA MINING APPLICATIONS IN CRIME PREVENTION

Data Mining techniques	Key techniques and methods	Purpose of research	Datasets used	Authors

Classification method	K nearest neighbor, boosted decision trees, naïve Bayesian, attribute induced method, random forests, advanced id3 algorithm, series finder, particle swarm optimization (PSO), Linear Discriminant Analysis (LDA)	Create prediction model that can accurately predict crimes, architecture to design framework for crime prevention, to detect hotspots, predict crimes using time and location of data, to detect suspicious emails about criminal activities and minimize them, predict the criminal of a crime	Open data catalogue in the city of Vancouver from 2003-2018, data from city agencies consisting of crime type, date and time it occurred, data from GIS and crime incident reports, Global terrorism database, database of crime incidents	(30), (33), (12), (7), (31), (15), (39), (40), (18), (3), (5)
Clustering method	K means clustering, dynamic time warping algorithm, mahanobolis distance, fuzzy c means algorithm, AK mode algorithm, Expectation Maximization algorithm, self-Organizing maps (SOM)	To predict crime prone areas, to predict crime category given time and location of crime, to solve new crime cases and prevent future attacks	NCRB website from 1971 to 2006, START Database from 2000 to 2011, Crime activities for three different countries san Francisco, Chicago and Philadelphia, historical data from police	(9), (1), (21), (20), (6), (29), (10), (41)
Association rule mining	Apriori algorithm, frequent pattern mining (FP growth), incremental temporal association rule, Dynamically adjusted weights	Link crime incidents, extract crime patterns, predict the location of the crime, narrow down possible suspects	Data from police dept., newspaper reports	(42), (4), (24), (13), (22)
Entity Extraction	Text mining, latent semantic indexing, named entity recognition, sentiment analysis	To extract crime patterns from texts	Newspapers in unstructured form, data from social network services and government agencies, START database from 2000 – 2011, data from mobile phones, data from social media	(32), (22), (16), (38), (35), (45)
Social Network analysis	SMACT model, degree, betweenness and closeness, BASF framework	To detect terrorist attacks, measure of centrality of a criminal, to, extract group leaders of a crime, to identify the gatekeepers (influential leaders that distribute information and goods to other members. Show the suspects and their connections e.g. (bank accounts, phone numbers	Data from multiple social media sources, call detail records, crime incident reports, financial transaction reports	(25), (27), (19), (35)

B. *Classification Techniques*

Classification techniques are one of the most fundamental and important Data Mining techniques for classifying observations based on some relevant attributes that are discovered from the database. With reference to the application of classification techniques in crime data mining, many applications have integrated more than one basic classification technique. Therefore, the subsequent overview is categorized in a sequential manner by each technique.

Decision Trees

The classification technique known as decision trees is used in [33], where the paper pointed out the need to live in a safe environment that is free of anger and attack. An enhanced ID3 algorithm was proposed to detect doubtful emails of the criminals. The objective to detect doubtful criminals' activities and minimize them was achieved by the Z- crime tool used for identifying suspicious emails. Advantage of the new model is its fast in classifying the object and construction is easy. However, Disadvantage is it doesn't handle noisy data perfectly and it chooses features based on the number of occurrences instead of their importance.

ID3 algorithms have the weaknesses of ability to pick attributes with many values. Although [44], [30] had previously suggested an improved ID3 algorithm and interest measure,

but the limitations have not yet been addressed until [43] solved the weaknesses and their scheme enhanced the ID3 algorithm. The experiment was conducted 100 times under the same software and hardware framework using mat lab and Weka tools, this shows that the new scheme deployed is reliable.

[15], uses crime data collected from socio economic data from 1990 census law enforcement and 1995 FBI. Two separate classification algorithms were compared, namely the naïve Bayesian algorithm and the decision tree algorithm for crime prediction. The authors experimented with the result and concluded the most effective as decision tree algorithm Decision tree algorithm is suggested for making analytical decisions as it can deliver accurate and interpretable outcomes, whereas naïve Bayesian is better suited to actual world problems because it requires fast analysis and short learning time. In(Wang & Liu, 2008), the techniques Decision Trees, Neural Networks, Support Vector Machines and Stochastic Boosting are used for hot spot detection in a large dataset for city development projects comprising 1.4 million events, 14 predictors and binary response factor.

In [40], Classification Techniques like Decision Trees, Naïve Bayes, Neural Network and SVM are implemented and evaluated for predicting hotspots and future occurrence of a crime. Using Naive Bayes Classifier has the advantage that it is simple and mingles faster than other algorithms while for SVM its simple to implement and performance is high which requires a lot of memory.

In [36], decision tree algorithm is joined with the reduction strategy of an attribute for analyzing the behavior of a criminal. Rule based Classification, Naïve Bayesian and C4.5 Decision Trees are used in [7] for preventing car insurance fraud. In [31] the paper proposed a system to accurately analyze the crime data and use the recommended data mining algorithm to uncover the hidden information from crime datasets in order to identify the criminal. Selection of appropriate data mining algorithm will be done by performance comparison of J48, Naïve Bayes and JRip (Ripper) against sample crime and criminal database. They compared these three for performance and found that Naïve Bayes was the most effective algorithm because it out preformed J48 and JRip algorithms.

Other classification techniques

In [18], some algorithms were reviewed namely; Linear Discriminant Analysis (LDA), SVM, KNN, Bayesian Belief and ANN. These are all supervised learning algorithms that predict the category of a crime. Particle Swarm Optimization (PSO) and ANN were incorporated in [3] to determine the essential features of a particular type of crime. A drawback of KNN is its very slow in predictions, and doesn't handle missing data correctly.

More recently, (Balasupramanian, Ephrem, & Al-barwani, 2017) suggested an architectural framework to cease online fraud transaction. Self-organizing Maps (SOM) takes the attributes as the input data, and the system would be trained for all customers and their transactions. Then the results would be compared with the customer's actual transaction data, and either reject or approve the request.

Cluster Analysis

Cluster Analysis is a method that is used to group observations where findings are similar within each group, and the clusters are different. Cluster Analysis was coupled with a Geographical Information System (GIS) to identify hot spots of crime in [9] where the authors analyzed the results of different Clustering techniques and described the concept of cluster relevance as the standard to identify a spot as" hot" or not in analyzing crimes.

[1], used a combination of Clustering techniques and Self Organizing Maps to evaluate the behavior of sex-offenders in UK. Their findings showed that crimes within a single cluster have strong similarities and can include crimes committed by the same criminal. Also, in (D. Kumar & Arti, 2015) k-means clustering was used for detecting crimes in India between 2000–2012 through four cases irrespective of the crime location and the type of the crime. K means algorithm is the easiest and most commonly used algorithm in clustering.

[21] developed a framework called Recap in India, to detect patterns of crime. K means algorithm was used to detect the hotspots of a crime. Drawback of the model is it has limited space and implementation is expensive. [6], in their survey talked about k means algorithm, AK mode algorithm and Expectation Maximization algorithms for finding similarity measures.

This would help police officers investigate and help to resolve unsolved cases more efficiently and more easily. A similarity measure is the distance with dimensions representing features of the objects.

In [29] a new path is implemented based on Mahanolobis distance, Euclidean distance and Minkowski distances to calculate the mean errors. Dynamic time warping technique is used to predict future occurrence of a crime from NCRBs website. An advantage of Dynamic Time Warping is that two sequences don't need to be on the same length.

In order to improve the efficiency of crime investigations for Indian police [10], introduced a crime analysis tool with an interactive interface to help in criminal investigations. In addition, the clustering technique is applied to identify hot spots for crime based on the Indian NCRB database.

[41] in their research, used an improved induced oriented algorithm for mapping out the hotspot of a crime. Spatial crime Data was preprocessed, then clustering phase using induced algorithm and finally the output is outlined as the specific hotspot.

Association Rule Mining

Association Rule Mining is a method that leverages relationships among attributes to uncover crucial information concealed within big data. They are rules generated from crime dataset based on frequents appearances of crime patterns to help the security agencies make a preventive action. In [42] raw data was gathered from supreme security committee in Libya. where Apriori algorithm was used to uncover the best association rules among the crimes and the criminal attributes. In [4] Apriori algorithm is used for detecting suspicious emails of criminal activities. This innovative approach was aimed at helping the investigators obtain information effectively and take appropriate action to reduce criminal activities.

[24], introduced an ITAR algorithm adopted in a crime pattern system. Their new algorithm has been applied to help detection of crime trends in a Hong Kong district and the outcomes have shown considerable improvements. In (Brown & Hagen 2003), the association techniques are used for law enforcement applications. The proposed approach automatically searches for similar patterns by using a new similarity measure with theoretical weights of information, among features of Robbery reports in Richmond Police Department database to link potential crimes committed by the same or a group of offenders. FP growth was used in [13] to produce recurring item sets between the mined crimes.

Entity Extraction

Entity Extraction discovers and classifies text elements into predetermined classes such as the names of the user, organizations, places, date, time etc. By using this method in the article on crime, we can obtain more information about crime such as the names of victims and suspects, the location of the crime, the date, the time etc. [32].

Text mining is the method of discovering patterns for the purpose of finding insights from very large text databases. Text mining is also known as Knowledge Discovery from Texts (KDT). [22] detected crime trends in Swahili newspapers using text mining technique to curtail future attacks. [16], developed a web-based crime analysis system. Swahili newspaper articles are crawled using a crawler, and the news articles are then marked either as crime or non-crime. Entities related to crime are selected from the articles and duplicates are removed. However, Latent semantic indexing was used in [38] to extract information from terror attacks. The method uses singular value decomposition (SVD) technique to identify the correct meanings of words based on their patterns.

The model in [35] uses the named entity recognition technique to identify names of suspects from crime related documents. Also, in [45], the model uses sentiment analysis to detect terrorism in Kenya using twitter data from social media. This will serve as a warning signal to law enforcements and as such terrorism would be prevented.

Social Network Analysis

Social Network Analysis (SNA) is a tool for defining valuable information based on the analysis of the social system among interactions. The proposed model in [25] aimed at collecting and interpreting strategic connections between the active criminals within a specified network structure. The SNA methodology has been used as a tool in [27] to help police detectives understand the behaviors of an offender, using real world crime data from Richmond City Police Department.

Social Media Analysis for Combating Terrorism (SMACT) model was proposed in [19] to address terrorism in developing countries. Suspected terrorists are traced through different social media sources by the criminals' photos, locations, phone numbers etc. In [35], System for Identifying the Influential Members of a Criminal Organization (SIIMCO) Was introduced to recognize the most powerful Criminal Group members. Additionally, the model also identified the relative importance of each criminal in a network by using the centrality measures namely degree, centrality and closeness formulas.

III. CONCLUSION

Crime tactics changes over time and continues to increase day by day. The changes and high occurrence of crime leads to concerns of knowing criminal behavior, forecasting crime, precise detection and handling vast quantities of crime data collected from various sources. This survey paper starts with a quick summary of crime emergence and Data Mining's relevance to crime identification, analysis, and prevention.

After a substantial survey, we are able to present a list of Data Mining techniques that are commonly used as regards to crime analysis. These techniques constitute

classification, cluster analysis, Association rule mining, entity extraction and social network analysis. Each technique has different algorithms and methods of analyzing crimes. This article is useful as a reference for researchers to analyze and classify data mining approaches in crime. Moreover, the data mining strategies analyzed in this survey can be used to detect suspects and identify the crime prone areas for a safer environment for people to live in. Table 1 serves as a useful tool or' fast reference' summarizing the applications of Data Mining in Crime, by providing useful information not only on the methods in each technique but also the datasets used.

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