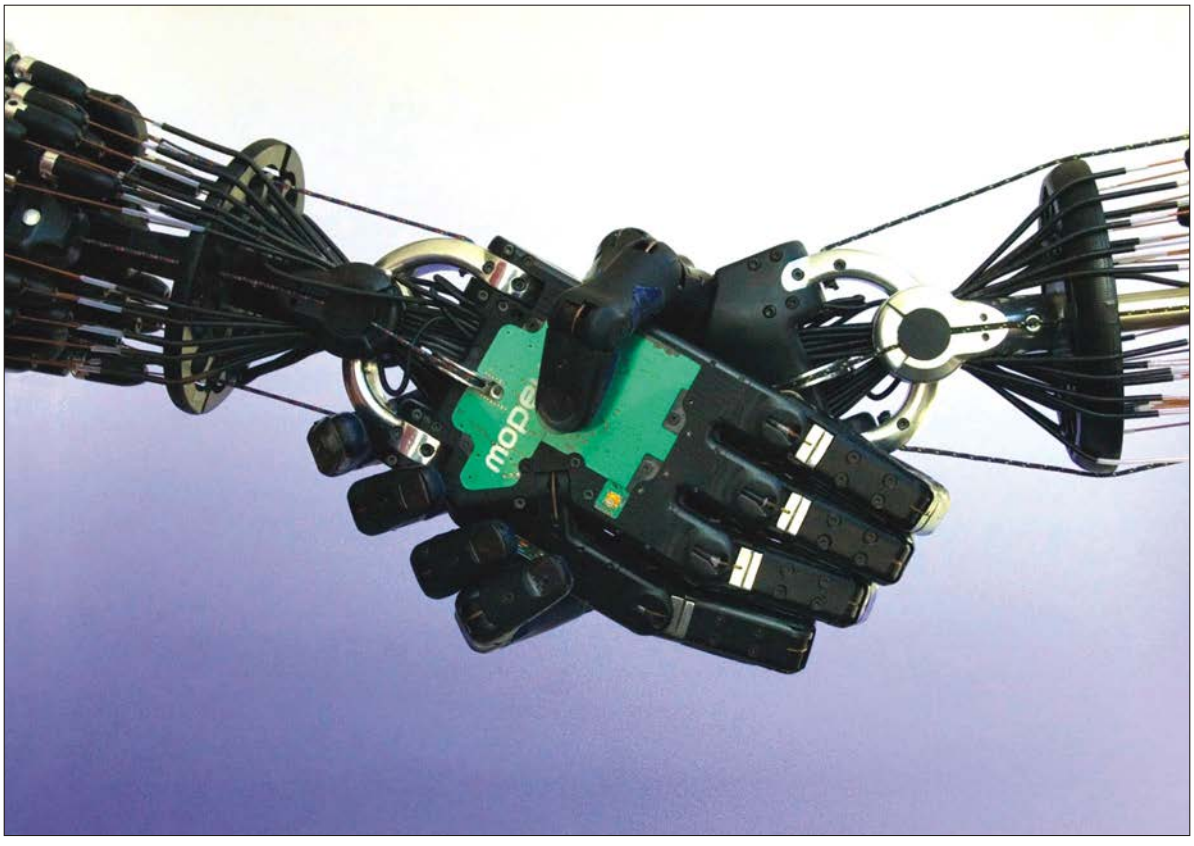

Journal of Artificial Intelligence

ISSN 1994-5450

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Artificial Intelligence 8 (1): 17-34, 2015
ISSN 1994-5450 / DOI: 10.3923/jai.2015.17.34

A Review on a Classification Framework for Supporting Decision Making in Crime Prevention

Noor Maizura Mohamad Noor, Siti Haslini Ab Hamid, Rosmayati Mohemad, Masita @ Masila Abdul Jalil and Muhammad Suzuri Hitam
School of Informatics and Applied Mathematics, Universiti Malaysia Terengganu, 21030, Kuala Terengganu, Terengganu, Malaysia

Corresponding Author: Noor Maizura Mohamad Noor, School of Informatics and Applied Mathematics, Universiti Malaysia Terengganu, 21030, Kuala Terengganu, Terengganu, Malaysia Tel: +6016-9806310

ABSTRACT

Increasing volume of crimes has brought a serious problem to many countries across the world. Crime prevention is an important component of an overall strategy to reduce crime and to strengthen public safety. Although, Supporting Decision Making (SDM) in crime prevention is an important topic but a comprehensive literature review on the subject has yet to be implemented. Thus, this study presents a systematic and comprehensive review on a classification framework for SDM in crime prevention. Forty four journal articles on the subject published between 2000 and October, 2015 were analyzed and classified into two categories of index crime (violent crime and property crime) and six classes of data mining techniques (prediction, classification, visualization, regression, clustering and outlier detection). The results of this study clearly show that data mining especially prediction and clustering techniques have been applied most extensively in both index crime categories. The main data mining techniques used for SDM in crime prevention are Bayesian, neural network and nearest neighbor. This study also addresses the gaps between SDM in crime prevention and the needs of practitioners to encourage more researches in crime analysis. Finally, it concludes with some suggestions for future research on SDM in crime prevention.

Key words: Decision making, crime prevention, crime analysis, data mining, decision support system

INTRODUCTION

Recently, increasing volume of crimes has brought a serious problem to many countries across the world. For an example, Malaysia is one of the fastest growing countries in Southeast Asia and one of the challenges faced is increasing of crime rate (Marzbali *et al*., 2012). According to the Royal Malaysia Police (RMP), incidences of crime can be categorized into two types which are index crimes and non-index crimes. Index crime is crimes that are normally reported and have sufficient significance to be considered as important as an indication towards the level of crime. On the other hand, non-index crime involves cases of crime that are not considered to be a measurement of crime stream (Abdullah *et al*., 2012). To handle the issue of increasing volume of crimes, the government introduced one of the Malaysian government agendas as stated in the National Key Result Area (NKRA) which is to reduce crime (Soh, 2012). The NKRA reduce crime includes the whole procedure of fighting crime, known as crime prevention, crime tracking, arrest, trial of offenders, prison and also rehabilitation. Moreover, it targets to increase community awareness and to

improve service delivery by the RMP. This study focuses on crime prevention which is an important component of an overall strategy to reduce crime and to strengthen public safety. Crime prevention refers to all actions and efforts that aim to reduce crime and fear of crime (Marzbali *et al*., 2012). Crime prevention can be defined as an effort to prevent crime or criminal offending in the first instance before the act has been committed (Welsh and Farrington, 2012). Government and public officials conduct a comprehensive effort to enhance the effectiveness of crime prevention (Li *et al*., 2010).

Now-a-days, Supporting Decision Making (SDM) in crime prevention has attracted a great concern and attention. Decision making is defined as the study of identifying and choosing alternatives based on values and preferences of decision maker (Harris, 2012). Decision making is very important in crime prevention in order to decide accurate actions and law enforcement strategies. The police needs valuable information such as crime statistics in order to increase the accuracy of selection decisions and to avoid biased analysis. Over the last two decades, researchers have developed several techniques to support law enforcement activities in order to prevent criminal act (Grubesic, 2006; Noor *et al*., 2011) and discover patterns of crime (Kaikhah and Doddameti, 2006; Li *et al*., 2010; Phillips and Lee, 2012). These works come from disciplines of behavior and psychology, statistics and artificial intelligence (Li *et al*., 2010). However, the main challenge faced by all law-enforcement organizations and intelligence-gathering is to analyze the growing volumes of crime data accurately and efficiently. As a solution, crime analysis can make an important contribution to the delivery of an effective and efficient police services and to how the police and their partners tackle crime (Chen *et al*., 2004).

Crime analysis can be defined as a profession and process in which a set of quantitative and qualitative techniques are used to analyze data valuable to police agencies and their communities (Bruce *et al*., 2014). Crime analysis includes the analysis of crime, criminals, crime victims, disorder, quality of life issues, traffic issues, internal police operations and its result support crime prevention and reduction strategies, criminal investigation and prosecution, patrol activities, problem solving and the evaluation of police efforts. There are four major categories of crime analysis recognized by International Association of Crime Analysts (IACA) which are crime intelligence analysis, tactical crime analysis, strategic crime analysis and administrative crime analysis (Bruce *et al*., 2014). Each type of crime analysis has a number of processes and sub-categories (Bruce *et al*., 2014).

Lately, the data mining approach has been exposed to be a proactive decision-support concept in preventing and predicting crime. Based on existing knowledge, criminology is one of the most important fields to apply data mining because it deals with high volume of crime data and complexity of relationship between data (Keyvanpour *et al*., 2011). Data mining is a great tool that allows criminal investigators who may lack extensive training as data analysts to discover huge databases efficiently and quickly (Chen *et al*., 2004). Moreover, crime analysis can produce a superior result by integrating data mining technique into Decision Support System (DSS). The DSS is required in crime analysis because it has the capability to improve the quality of decision making for crime prevention. The DSS can be defined as an integrated, interactive computer system, consists of analytical tools and information management capabilities and is designed to assist decision makers in solving quite large and unstructured problems (Sieker *et al*., 2006). The DSS makes full use of suitable computer techniques and through the interactive human-machine model, it helps to improves the effectiveness of decision-making about semi-structures and non-structures (Zhou *et al*., 2008). In DSS, there are three fundamental components which are Model Base

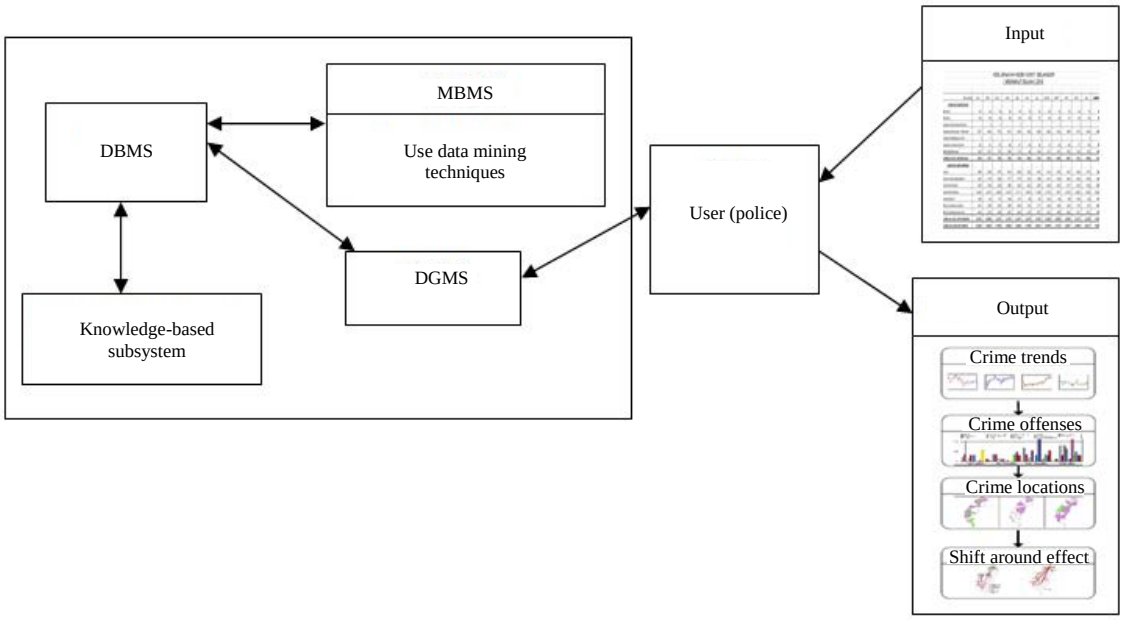

Fig. 1: Conceptual framework of DSS for SDM in crime prevention

Management System (MBMS), Database Management System (DBMS) and Dialog Generation and Management System (DGMS) as depicted in Fig. 1. DBMS serves as a data bank for the DSS while, MBMS transforms data from DBMS into information that is useful in decision making by using Artificial Intelligence (AI) and fuzzy logic. The DGMS or user interface is used to improve the ability of the system user to utilize and benefit from DSS. For instance, monthly crime volume for each crime type that covered for one year was recorded by the police. By using this data, DBMS can store, update, delete and generate report. To transform raw crime data into information, MBMS will communicate with DBMS. All information and reports generated will be displayed using DGMS.

Currently, a number of review articles on SDM in crime prevention have also appeared in journal publication. Chen *et al*. (2004), for example have presented a general framework for crime data mining based on their experiences gained through Coplink project. Krishnamurthy and Kumar (2012) have surveyed data mining technique on crime data analysis that focused only on data preprocessing and clustering method. Fredrick and Patrick (2012) presented a survey of data mining methods for crime analysis and visualization. They concentrated on crime spatial analysis and visualization. Nissan (2012) surveyed on forensic applications of data mining to fraud and crime intelligence or investigation within law enforcement. Roth *et al*. (2013) presented a survey on current practices and unmet needs for spatiotemporal crime analysis in U.S. law enforcement agencies. Based on the previous review articles, the researchers only provide limited review on data mining technique. Nevertheless, this study presents the up-to-date and comprehensive review of data mining application to support decision making in crime prevention.

This study has three objectives: (1) Develop a framework for classifying the application of data mining for SDM in crime prevention, (2) Provide a systematic review of existing research articles on the application of data mining in crime prevention and (3) Use the review and framework for generating roadmap for researchers looking for better understand this field.

The rest of the study is structured as follows: Section 2 presents the methodological framework for research. Section 3 proposes classification framework on application of data mining for SDM in crime prevention. Section 4 analyzes SDM in crime prevention research according to this classification framework. Lastly, section 5 provides conclusion and future research directions.

METHODOLOGICAL FRAMEWORK FOR RESEARCH

The methodological research framework for this study is modified from other review study (Ngai *et al*., 2011). This methodological research framework consists of three phases: Research definition, research methodology and research analysis as displayed in Fig. 2.

In phase 1, this study identifies the area of research, the expected research goal and the scope of research. The area of research is academic research on SDM in crime prevention using data mining techniques. The expected research goal is to create a classification framework on application of data mining for SDM in crime prevention and to suggest future research directions. The research scopes are the literature on application of data mining for SDM in crime prevention, applied index crime dataset and published for 16 year period between 2000 and 2015 which is summarized to provide knowledge for researchers in this area. The period is important because the internet was

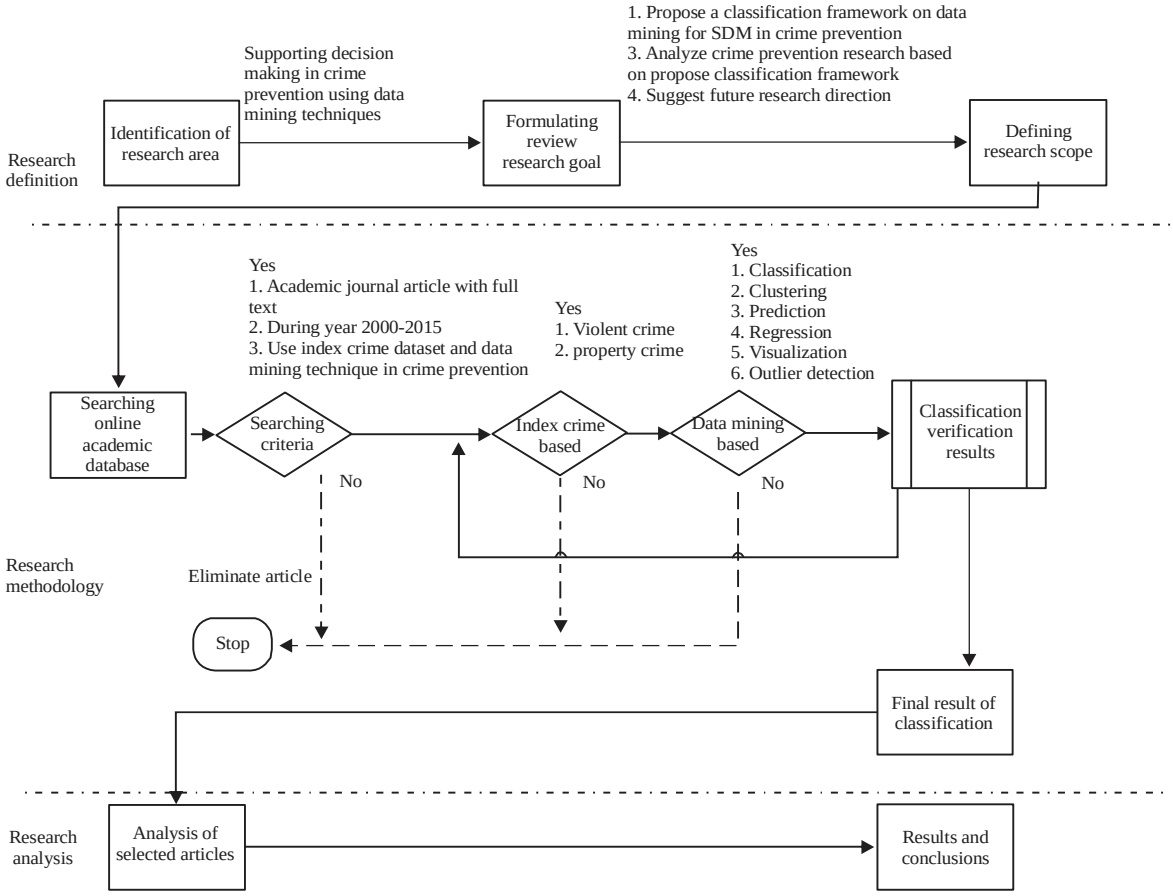

Fig. 2: Methodological framework for research

opened to general users in 2000 and the widespread availability of information and communication technologies have played an important role in the development of methods for collecting data from online databases (Liao *et al*., 2012).

In phase 2, this study identifies the suitable criteria to search and select articles. This study also constructs a framework for classifying the selected articles. To provide a comprehensive listing of journal articles, this study searches online academic databases such as Science Direct, Springer-Link journals, Academic Search Premier, ProQuest and World Scientific.Net. These databases contain most academic journals in full text English version. The searching process is based on specific keywords like "Crime data mining", "Crime prevention" and "Crime analysis".

The review and classification process was done carefully and only articles related to SDM in crime prevention that applied data mining techniques and index crime dataset were selected. Firstly, the articles must have been published in academic journals with availability of full text versions. Secondly, the articles had to have been published within the year 2000 until October, 2015. Thirdly, the articles had to use index crimes dataset, apply data mining techniques and discuss their application for SDM in crime prevention. Forty four articles were chosen for classification.

In the last phase, this study analyzes the selected articles to make some conclusions and propose some future research directions. Section 4 presents the details result of the analysis based on the proposed classification framework.

CLASSIFICATION FRAMEWORK ON DATA MINING FOR SDM IN CRIME PREVENTION

In this section, this study proposes a graphical conceptual classification framework for the available literature on applications of data mining techniques for SDM in crime prevention. The classification framework, which is depicted in Fig. 3 is based on a literature knowledge on the nature of data mining research (Chen *et al*., 2004; Ngai *et al*., 2011) and index crime based on Uniform Crime Reporting (UCR) program (FBI., 2004). The proposed classification framework for index crime is based on the part 1 offenses in the UCR program published by the U.S. Federal Bureau of Investigation (FBI), because it is one of the best established frameworks for crime. Figure 3 consists of two layers. The first layer (layer A) contains two index crime categories which

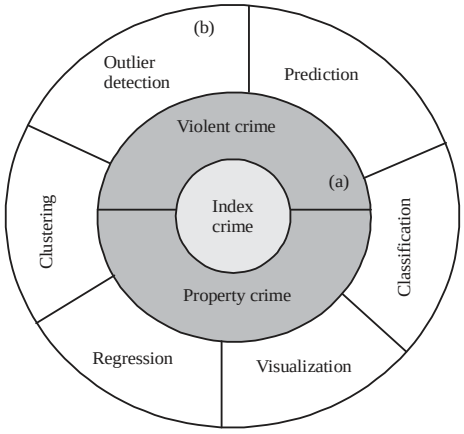

Fig. 3: Conceptual framework for classifying data mining for SDM in crime prevention

are violent and property crimes. The second layer (layer B) contains six data mining classes which include prediction, classification, visualization, regression, clustering and outlier detection. This study provides a brief explanation of the proposed classification framework with references in the following sections.

Classification for index crime: Index crime is the crimes that considered quite serious, tend to be reported more reliably than others and are reported directly to the police. According to the RMP, index crime refers to types of crime that occur with sufficient regularity and significance that they collectively serve as a meaningful index to the overall crime situation (PMDU., 2010). In this study, index crime is classified into two main categories. Table 1 shows index crimes category and list of crime types for each category. The first category is property crime in which they commit offenses involving loss of property and no use of violence by the perpetrator (Soh, 2012). In this study, property crime includes burglary, theft, vehicle theft and arson where, burglary is the unlawful entry of a structure to commit a felony or a theft and theft is defined as the unlawful taking, carrying, leading or riding away of property from the possession or constructive possession of another (FBI., 2004). According to UCR program, vehicle theft is the theft or attempted theft of a motor vehicle where, motor vehicle is self-propelled and runs on land surface and not on rails. On the other hand, arson is defined as any willful or malicious burning or attempt to burn with or without intent to defraud, a dwelling house, public building, motor vehicle or aircraft and personal property of another, etc. (FBI., 2004).

The second category is violent crime which generally includes crimes of violence that are pretty common and significant in occurrences (Soh, 2012). In this study, violent crime includes murder, rape, robbery and aggravated assault where, murder is the willful (non-negligent) killing of one human being by another (FBI., 2004). West's Encyclopedia of American Law similarly define murder as unlawful killing of another person without justification or valid excuse. Rape is defined as penetration, no matter how slight of the vagina or anus with anybody part or object or oral penetration by a sex organ of another person without the consent of the victim (FBI., 2014). According to UCR program, robbery is defined as the taking or attempted taking of anything of value from the care, custody or control of a person or persons by force or treat of force or violence and/or by putting the victim in fear and aggravated assault is defined as an unlawful attack by one person upon another for the purpose of inflicting severe or aggravated bodily injury (FBI., 2004).

Classification for data mining applications and techniques: There are six data mining application classes which include prediction, classification, visualization, regression, clustering and outlier detection (Ngai *et al*., 2011). Prediction is based on the patterns of a crime data set to estimate numeric and ordered future values (Ngai *et al*., 2011). Among the most commonly used prediction techniques are neural networks and Bayesian method. Classification discovers common properties among different crime entities and organizes them into predefined classes (Chen *et al*.,

Table 1: Classification for index crimes based on UCR (FBI., 2004)

Index crime category	Crime type
Property crime	Burglary, theft, vehicle theft and arson
Violent crime	Murder, rape, robbery and aggravated assault

2004). This technique frequently used to predict crime trends. Some of the famous classification techniques are Naive Bayes classifier, decision tree and fuzzy logic techniques. Visualization refers to an easily understandable presentation of data and to methodology that converts complicated data characteristics into clear patterns to allow users to view the complex patterns or relationships uncovered in the data mining process (Chen *et al*., 2004). From the literature, visualization techniques have demonstrated an enormous capacity to analyze crime data.

Regression is a statistical process to estimate the relationships between variables (Ngai *et al*., 2011). The regression technique normally applies mathematical method such as Ordinary Least Square (OLS). Clustering known as data segmentation or partitioning is the task to discover groups and structures in the data that are in some way or another "Similar", without using known structures in the data. Some of the common clustering techniques are the K-mean and self-organizing map (Li *et al*., 2010; Li and Juhola, 2014a). Outlier detection uses specific measurement to study data that differs markedly from the rest of the data (Chen *et al*., 2004).

ANALYSIS OF SDM IN CRIME PREVENTION RESEARCH BASED ON THE PROPOSED CLASSIFICATION FRAMEWORK

This study provides a review of classification framework for SDM in crime prevention. For the classification of index crime, this study sorted the articles accordingly to the categories of violent crime and property crime. Some of the selected articles apply both data on property crime and violent crime and thus this study categorized those articles as "Both category". For the data mining classification, this study identified six data mining application classes together with their techniques.

The distribution of the 44 articles classified into the proposed classification framework is depicted in Table 2. The table contains information on article number, crime category, crime type and data mining class and technique. Although, some researches using data on index crime together with non-index, this study captures only crime types that fall under index crime. Based on Table 2, it is worth noting that murder is the highest concern in violent crime while burglary is the main concern in property crime. The popular data mining application classes are prediction (34.1% or 15 of the 44 articles) and clustering (22.7% or 10 of the 44 articles). Regression is applied in four articles (9.1%), followed by classification (6.8% or 3 of the 44 articles) and visualization (4.5% or 2 of the 44 articles). Some of the articles apply combination of data mining application classes such as clustering and classification (9.1%, 4 of the 44 articles) and clustering and visualization (6.8% or 3 of the 44 articles). Outlier detection is only applied in one article (Malathi and Baboo, 2011) combined with clustering and classification techniques. The limited use of data mining technique of outlier detection may be due to the difficulty of detecting outliers (Ngai *et al*., 2011). Similarly, visualization also has shown a limited used and normally applied with clustering technique. Chen *et al*. (2004) pointed out that visualization has the highest analysis capability in crime data mining. Moreover, the main data mining techniques used in the articles are Bayesian, neural network (including self-organizing map) and nearest neighbor. Besides, decision tree, k-mean and Ordinary Least Squares (OLS) appear in more than one article.

A complete list of the 44 selected articles is presented in Table 3-5. Based on Table 3-5, it can be seen clearly that strategic crime analysis is the famous type of crime analysis among researchers (47.7%, 21 of the 44 articles) followed by tactical crime analysis

Table 2: Research on data mining techniques for SDM in crime prevention

Article number	Crime category	Crime type	Data mining class	Data mining technique	References
1	Property crime	Burglary, theft	Classification	Case based reasoning	Ribaux and Margot (2003)
2	Property crime	Burglary	Clustering	Nearest Neighbor Hierarchical (NNH) spatial clustering algorithm	Malleson *et al.* (2010)
3	Property crime	Burglary	Clustering and classification	Unknown	Sukanya *et al.* (2012)
4	Property crime	Burglary	Prediction	Population Reconstruction Model (PRM) and BurgdSim model	Malleson and Birkin (2012)
5	Property crime	Theft and handling stolen goods, robbery, burglary, fraud and forgery	Regression	Time series regression model	Jennings *et al.* (2012)
6	Property crime	Theft	Classification	Adaptive Network-based Fuzzy Inference System (ANFIS), Artificial Neural Networks (ANN), Classification and Regression Tree (C and RT)	Patel and Singh (2013)
7	Property crime	Burglary	Clustering and visualization	Geospatial Discriminative (GD) Patterns	Wang *et al.* (2013)
8	Property crime	Burglary	Prediction	Improved Knox method	Johnson (2013)
9	Property crime	Burglary	Clustering	Cut clustering algorithm	Borg *et al.* (2014)
10	Property crime	Theft	Prediction	Exponential smoothing	Camacho-Collados and Liberatore (2015)
11	Violent crime	Murder, rape, assault	Regression	Vector autoregressive (VAR) and ordinary least squares (OLS)	Saridakis (2004)
12	Violent crime	Murder, rape, robbery, and auto theft	Clustering	Neural network	Kaikhah and Doddameti (2006)
13	Violent crime	Unknown	Clustering, classification and outlier detection	K-means and Density-Based spatial clustering Application with Noise (DBScan), decision tree, generalize tree	Malathi and Baboo (2011)
14	Violent crime	Murder	Prediction	Fuzzy time series technique	Shrivastav and Ekata (2012)
15	Violent crime	Murder	Prediction	Bayesian model and grid search model	Yan *et al.* (2012)
16	Violent crime	Robbery and murder	Clustering and classification	Binary clustering and auto correlation model	Mande *et al.* (2012)
17	Violent crime	Murder, rape and robbery, assault	Clustering	Self-organizing map	Li and Juhola (2014a)
18	Violent crime	Murder	Prediction	Analytic Hierarchy Process (AHP) and Fuzzy Analytic Hierarchy Process (FAHP)	Dong *et al.* (2014)
19	Violent crime	Murder	Prediction	Bayesian	Wu and Wang (2014)
20	Violent crime	Robbery and aggravated assault	Regression	Cross-lagged autoregressive structural equation model	Boggess and Maskaly (2014)
21	Violent crime	Homicide and gun crime	Prediction and visualization	Kernel-based hotspot maps	Mohler (2014)
22	Violent crime	Murder, assault, robbery, rioting, mugging, sexual abuse	Clustering and classification	K-mean and KNN classification	Tayal *et al.* (2015)
23	Violent crime	All types	Prediction	Bayesian	Law *et al.* (2015)
24	Both category	All types	Prediction	Neural network	Palocsay *et al.* (2000)

Table 2: Continue

Article number	Crime category	Crime type	Data mining class	Data mining technique	References
25	Both category	Robbery, burglary, simple and aggravated assault	Prediction	Naive bayes and exponential smoothing	Gorr *et al.* (2003)
26	Both category	All types	Clustering	Choropleth mapping, local spatial statistics, nearest neighbor hierarchical clustering and non-hierarchical cluster	Ackerman and Murray (2004)
27	Both category	All types	Clustering	Fuzzy clustering	Grubesic (2006)
28	Both category	All types	Clustering and visualization	Fuzzy Self-Organizing Map (FSOM) and Fuzzy C-Means (FCM)	Li *et al.* (2010)
29	Both category	All types	Clustering and classification	Self-organizing map and Multi-Layer Perceptron (MLP) neural network	Keyvanpour *et al.* (2011)
30	Both category	All types	Clustering	Horizontal-view approach	Lee and Estivill-Castro (2011)
31	Both category	All types	Regression	Ordinary Least Squares (OLS)	Hooghe *et al.* (2011)
32	Both category	All types	Visualization	Global minimum edge weight and kruskal's algorithm	Phillips and Lee (2012)
33	Both category	All types	Prediction and regression	Geographic Information System (GIS) and geographic weighted regression	Ferreira *et al.* (2012)
34	Both category	All types	Prediction	Autoregressive Integrated Moving Average (ARIMA) and fuzzy alpha-cut	Noor *et al.* (2013)
35	Both category	Theft, sex crime, murder, and arson gang	Clustering	Affinity propagation algorithm	Bsoul *et al.* (2013)
36	Both category	All types	Prediction	Exploratory Data Analysis (EDA) and adjusted decomposition technique	Ismail and Ramli (2013)
37	Both category	Murder, rape, robbery, assault, burglary, larceny and motor vehicle theft	Prediction	Space-time autoregressive (ST-AR) model	Shoesmith (2013)
38	Both category	Burglary, robbery, assault and theft	Classification	Natural Language Processing (NLP), similarity measure and machine learning (Naive Bayes' classifier)	Ku and Leroy (2014)
39	Both category	Theft, burglary, motor vehicle theft, assault, robbery, weapons violation, sex offense, arson and homicide	Prediction	Kernel Density Estimation (KDE) and Latent Dirichlet Allocation (LDA)	Gerber (2014)
40	Both category	Aggravated assault, burglary, forcible rape, theft (larceny, motor vehicle), robbery and murder	Clustering	Self-organizing map, k-mean clustering, nearest neighbor searching, logistic discriminant analysis and decision tree	Li and Juhola (2014b)
41	Both category	All types	Visualization	Linkchart	Rossy and Ribaux (2014)
42	Both category	All types	Clustering and visualization	Self-organizing map	Alruily *et al.* (2014)
43	Both category	All types	Clustering	Bivariate K-function	Conrow *et al.* (2015)
44	Both category	All types	Prediction	Bayesian	De Zoete *et al.* (2015)

Table 3: Property crime

Type of crime analysis	Main objectives	DSS	References
Criminal intelligence analysis	To describe a possible structure of the memory for the analysis of serial burglary and theft	No	Ribaux and Margot (2003)
Tactical crime analysis	To demonstrate the strengths, flexibility and applicability of an individual-based model combined with a behavioral model (Physical conditions, emotional states, cognitive capabilities and social status (PECS) framework) to simulate residential burglary	No	Malleson *et al*. (2010)
Tactical crime analysis	To present the method for identifying the hotspot of the criminal activities and finding the criminals by using clustering and classification algorithm	No	Sukanya *et al*. (2012)
Strategic crime analysis	To suggest that individual representations of criminal behavior can be enhanced by combining them with an agent-based model and a microsimulation technique For burglary, the target is identification of individual households	No	Malleson and Birkin (2012)
Strategic crime analysis	To develop a model of the effect of changes in socio-economic variables (unemployment, inequality, welfare spending and incarceration) on property crime rates by undertaking time series analysis of social and economic determinants of property crime (using official statistics on recorded crime for England and Wales from 1961-2006)	No	Jennings *et al*. (2012)
Administrative crime analysis	To apply various advanced pattern mining algorithm that can be used to distinguish copy operation from non-copy operations and reduce the false positives that are generated by stochastic forensic method	No	Patel and Singh (2013)
Strategic crime analysis	To present a spatial data mining framework to study crime hotspot through their related variable and develop a novel model-Hotspot Optimization Tool (HOT) in order to improve the identification crime hotspots	No	Wang *et al*. (2013)
Crime intelligence analysis	To explore the phenomenon through the examination of individual offender data to establish if time and space patterns are understandable in the spatial behavioral patterns of the individual burglar	No	Johnson (2013)
Administrative crime analysis	To introduce and describe the DSS and the structured data collection of crime scene as well as to evaluate one particular type of analysis component	Yes	Borg *et al*. (2014)
Administrative crime analysis	To present Predictive Police Patrolling DSS (P3-DSS) in collaboration with the Spanish National Police Corps (SNPC) for the efficient distribution of police officers in a territory under the jurisdiction of a police department with the aim to reduce the likelihood of criminal acts	Yes	Camacho-Collados and Liberatore (2015)

DDS: Decision support system

Table 4: Violent crime

Type of crime analysis	Main objectives	DSS	References
Strategic crime analysis	To provide a systematic investigation of both economic and social causes of violent crime offences in the US between 1960- 2000	No	Saridakis (2004)
Strategic crime analysis	To present a novel knowledge discovery technique using clustering technique for murder, rape, robbery and auto theft crime in United States cities	No	Kaikhah and Doddameti (2006)
Strategic crime analysis	To develop a crime analysis tool for Indian scenario using various type of data mining techniques that can help law enforcement department to handle crime investigation efficiently.	No	Malathi and Baboo (2011)
Strategic crime analysis	To investigate the applicability of fuzzy time series technique for crime prediction and get some reliable prediction for crime incidents for a lead year	No	Shrivastav and Ekata (2012)
Tactical crime analysis	To propose and test integrated model (Bayesian and Grid search model) according to historical serial crime samples for determining the most probable offender anchor point	No	Yan *et al.* (2012)
Tactical crime analysis	To present a novel methodology to identify a criminal based on the witness/clue at the crime spot.	No	Mande *et al.* (2012)
Strategic crime analysis	To apply the SOM to mapping countries with different situations of crime	No	Li and Juhola (2014a)
Tactical crime analysis	To provide an overview of new prediction model with comparison to other model	No	Dong *et al.* (2014)
Tactical crime analysis	To propose a prediction technique of crime's incidence that can provide a reference for the identification of psychological problems investigation of criminal the cases	No	Wu and Wang (2014)
Strategic crime analysis	To investigate the relationship between disorder and crime using a specified model that can incorporates the independent impacts of neighborhood factors and contributes for the potential reciprocal relationship over time between disorder and the influence of nearby neighborhood	No	Boggess and Maskaly (2014)
Strategic crime analysis	To develop a methodology for the prediction of homicide, along with precursory gun crimes with an application to predictive policing	No	Mohler (2014)
Tactical crime analysis	To propose an approach for crime detection and criminal identification (CDCI) using data mining techniques (DMT) for Indian cities	No	Tayal *et al.* (2015)
Tactical crime analysis	To analyze crime hotspot using a Bayesian spatiotemporal modeling approach while addressing the small problem and overcoming limitations of conventional frequentist methods	No	Law *et al.* (2015)

Table 5: Both index crime categories

Type of crime analysis	Main objectives	DSS	References
Tactical crime analysis	To apply neural network to generate case-by-case results in criminal recidivism	No	Palocsay *et al*. (2000)
Strategic crime analysis	To compare the forecast accuracy of univariate time series models with naïve methods using case study of Pittsburgh, PA	No	Gorr *et al*. (2003)
Strategic crime analysis	To establish an analytical and theoretical framework by employing both qualitative and quantitative technique to evaluate the relationship between aspects of place and the clustering of crime	No	Ackerman and Murray (2004)
Tactical crime analysis	To use fuzzy clustering for hot-spot detection	No	Grubesic (2006)
Strategic crime analysis	To apply Fuzzy Self-Organizing Map (FSOM) and rule extraction algorithm to analyze crime statistical data for 20 country police bureaus in Taiwan from 2003-2004 and produced results that can help police in criminal incidents prevention	Yes	Li *et al*. (2010)
Tactical crime analysis	To propose crime matching framework by using data mining technique for detecting and investigating crime	No	Keyvanpour *et al*. (2011)
Tactical crime analysis	To present two methods for exploratory analysis and detail algorithms to explore massive databases	No	Lee and Estivill-Castro (2011)
Strategic crime analysis	To determine what specific aspect of deprivation is most powerful in explaining crime rates	No	Hooghe *et al*. (2011)
Strategic crime analysis	To present a framework that allows autonomous exploratory analysis and knowledge discovery in massive real aggregated crime dataset	No	Phillips and Lee (2012)
Strategic crime analysis	To combine statistical methods and spatial model created with geographic information system based on police crime report	Yes	Ferreira *et al*. (2012)
Strategic crime analysis	To propose crime forecasting system using combination of ARIMA model and fuzzy alpha-cut in order to generate more accurate forecasting result with minimum error	Yes	Noor *et al*. (2013)
Tactical crime analysis	To enhance the reliability of document clustering of crime document by efficient k-mean as well as the extraction features of crime document. Then, it is applied for crime document clustering	No	Bsoul *et al*. (2013)
Strategic crime analysis	To identify crime patterns using exploratory data analysis and univariate forecasting technique in Kedah, Malaysia	No	Ismail and Ramli (2013)
Tactical crime analysis	To apply both established time series modeling techniques and the recently advanced space-time autoregressive (ST-AR) models to generate medium-and long-term forecasts of property and violent crime rates at the national, regional and state levels using UCR statistics	No	Shoesmith (2013)
Tactical crime analysis	To investigate how text analysis and classification technique can be applied to enhance e-government (law enforcement agency) by developing DSS	Yes	Ku and Leroy (2014)
Strategic crime analysis	To quantify the crime prediction gains achieved by adding Twitter derived information to standard crime prediction approach, recognize existing text processing tools and associated parameterizations that can be applied effectively in the analysis of tweet as well as to identify performance bottlenecks that most affect the Twitter-based crime prediction approach	Yes	Gerber (2014)
Strategic crime analysis	To apply the SOM to the fields of macroscopically exploring into multidimensional data of development of criminal phenomena and the aim of study is to seek an innovative field where artificial intelligence can be used to simplify the analysis	No	Li and Juhola (2014b)
Crime intelligence analysis	To propose a collaborative approach to incorporate forensic case data into crime investigation using criminal intelligence analysis and visualization	No	Rossy and Ribaux (2014)
Tactical crime analysis	To propose Crime Profiling System (CPS) to extract meaningful information (crime type, crime location and nationality) from an unannotated corpus to generate summarizations to automatically construct dictionaries and to cluster Arabic crime texts	No	Alruily *et al*. (2014)
Strategic crime analysis	To determine whether there was space-time interaction between alcohol outlets and violent crime events in buffalo, New York	No	Conrow *et al*. (2015)
Tactical crime analysis	To describe how Bayesian network can be used to model different evidential structures that can occur when linking crimes and how it assists in understanding the complex underlying dependencies	No	De Zoeto *et al*. (2015)

DDS: Decision support system

(38.6% or 17 of the 44 articles), criminal intelligence analysis (6.8%, 3 of the 44 articles) and administrative crime analysis (6.8% or 3 of the 44 articles). Boba (2001) highlights the primary purposes of strategic crime analysis are to assist in the identification and analysis of long-term problems and to conduct studies to investigate or evaluate relevant responses and procedures. In addition, only 7 out of 44 articles applied DSS in their researches. Therefore, there is still a room for future research on the application of data mining technique combined with a DSS to support decision making in crime prevention.

The following subsections present further analysis of data mining techniques for SDM in crime prevention.

Distribution of articles by year: Table 6 presents the distribution of articles by index crime and publication year. Based on this Table 6, research in both category of index crime is the most prominent and only a few studies that focus on a specific category of index crimes. As depicted in Table 6, this study identified only 13 articles for violent crime (29.5%) and 10 articles for property crime (22.7%). This study believes that researchers prefer to focus on both categories (47.7%, 21 of the 44 articles) instead of a specific category of index crime and this will continue to be the case. This situation shows that both categories of index crime are more or less equally important. Moreover, according to Table 6, it shows that none of the published articles within selection criteria in year 2001, 2002, 2005 and 2007-2009. The number of published articles started to increase since year 2011 until 2014 and this study is confident that this situation will continue in year 2015 and in the future.

Distribution of articles by journal: Table 7 shows the distribution of the 44 articles by the journal in which they appeared. The articles related to the use of data mining techniques for SDM in crime prevention are distributed across 32 journals that cover a wide range of fields. This result shows that the application of such techniques for SDM in crime prevention has attracted great attention from scholars in different disciplines. Journals that contain the most relevant articles are (1) Computers, Environment and Urban Systems, (2) Expert Systems with Applications, (3) International Journal of Forecasting and (4) Science and Justice where, each of

Table 6: Classification of articles by the categories of index crime and publication year

Index crime/year	Violent crime	Property crime	Both category
2000			1
2001			
2002			
2003		1	1
2004	1		1
2005			
2006	1		1
2007			
2008			
2009			
2010		1	1
2011	1		3
2012	3	3	2
2013		3	4
2014	5	1	5
2015	2	1	2
Total	13	10	21

Table 7: Distribution of 44 articles by journal title

Journal title	Article number (Refer Table 2)	Percentage (%)
Advanced Materials Research	15	2.3
Applied Artificial Intelligence	30	2.3
Applied Geography	8, 43	4.5
Applied Intelligence	12	2.3
Applied Mechanics and Materials	18, 19	4.5
British Journal of Criminology	31	2.3
Cities	26	2.3
Computers, Environment and Urban Systems	2, 4, 7	6.8
Decision Support Systems	10, 39	4.5
Digital Investigation	6	2.3
Electronic Journal Information Systems Evaluation	33	2.3
European Journal of Law and Economics	11	2.3
Expert Systems with Applications	9, 28, 32	6.8
Geographical Analysis	23	2.3
Government Information Quarterly	38	2.3
Information Processing and Management	42	2.3
International Journal of Advanced Research in Computer Engineering and Technology	3	2.3
International Journal of Computer Applications	13	2.3
International Journal of Computer Science and Engineering Technology	14	2.3
International Journal of Engineering Research and Applications	16	2.3
International Journal of Forecasting	21, 25, 37	6.8
International Journal of Law, Crime and Justice	5	2.3
International Journal of Society Systems Science	40	2.3
Journal of Applied Sciences	34	2.3
Journal of Knowledge, Culture and Communication	17, 22	4.5
Journal of Quantitative Criminology	27	2.3
Procedia Computer Science	29	2.3
Procedia-Social and Behavioral Sciences	36	2.3
Procedia Technology	35	2.3
Science and Justice	1, 41, 44	6.8
Socio-Economic Planning Sciences	24	2.3
Social Science Research	20	2.3
Total		100.0

the journals contains 3 of the 44 articles (6.8%). Next, the journals that contain the second relevant article are (1) Applied Geography, (2) Applied Mechanics and Materials, (3) Decision Support Systems and (4) Journal of Knowledge, Culture and Communication where, each of the journals contains 2 of the 44 articles (4.5%).

CONCLUSION, LIMITATIONS AND FUTURE WORKS

Crime is one of the biggest problems in cities across the world and crime prevention is one of the solutions to reduce crime. Now-a-days, SDM for crime prevention has attracted a great concern and attention from researchers. One of the solutions to support decision making for crime prevention is by using data mining technique (Keyvanpour *et al*., 2011). Although the importance of data mining techniques for SDM in crime prevention has been recognized, a comprehensive classification framework or a systematic review of their application for SDM in crime prevention research studies is lacking. Therefore, this study conducts a review of academic articles and propose classification framework on data mining for SDM in crime prevention.

The results of this study lead to the following conclusions. Firstly, based on 2 categories on index crime, researches in both categories have attracted the greatest attention from researchers. Secondly, the famous data mining application classes applied by many researchers are prediction and clustering. In addition, the main data mining techniques used in the articles are Bayesian, neural network (including self-organizing map) and nearest neighbor while, decision tree, Bayesian,

k-mean and OLS appear in more than one articles. Thirdly, most of the selected articles in SDM in crime prevention apply data mining technique for strategic crime analysis. Finally, only several of articles applied DSS in their researches and studies.

This study predicts that the number of articles on application of data mining for SDM in crime prevention will be increased in the future due to more attention from researchers and also governments. For an example, to handle the issue of increasing volume of crime, the Malaysia government has introduced one of the agendas as stated in NKRA which is to reduce crime (Soh, 2012).

This study has two main limitations. Firstly, this review considered only articles written in english. It is believed that articles regarding application of data mining technique for SDM in crime prevention have also been published in other languages. Future research could be extended to include articles published in other languages. Secondly, this review applied several key words to search well-known online databases for articles published from 2000 until October, 2015. This study also limited for index crimes. A future review could be extended in scope in order to produce a better result.

ACKNOWLEDGMENTS

This work was supported by Fundamental Research Grant Scheme (FRGS) under Ministry of Education (MOE) with grant number 59289. A special thank is also accorded to Criminal Investigation Department of the Royal Malaysia Police for its support and cooperation in providing information.

REFERENCES

Abdullah, A., N.A. Razak, M.N.M. Salleh and S.R.M. Sakip, 2012. Validating crime prevention through environmental design using structural equation model. Procedia Social. Behav. Sci., 36: 591-601.

Ackerman, W.V. and A.T. Murray, 2004. Assessing spatial patterns of crime in Lima, Ohio. Cities, 21: 423-437.

Alruily, M., A. Ayesh and H. Zedan, 2014. Crime profiling for the Arabic language using computational linguistic techniques. Inform. Process. Manage., 50: 315-341.

Boba, R., 2001. Introductory Guide to Crime Analysis and Mapping. U.S. Department of Justice, Office of Community Oriented Policing Services, USA., Pages: 74.

Boggess, L.N. and J. Maskaly, 2014. The spatial context of the disorder-crime relationship in a study of Reno neighborhoods. Social Sci. Res., 43: 168-183.

Borg, A., M. Boldt, N. Lavesson, U. Melander and V. Boeva, 2014. Detecting serial residential burglaries using clustering. Expert Syst. Appl., 41: 5252-5266.

Bruce, C.W., R.B. Santos and J.B. LeBlanc, 2014. Definition and types of crime analysis. Standards, Methods & Technology (SMT) Committee White Paper 2014-02, October 2014, International Association of Crime Analysts (IACA), Overland Park, KS., USA.

Bsoul, Q., J. Salim and L.Q. Zakaria, 2013. An intelligent document clustering approach to detect crime patterns. Procedia Technol., 11: 1181-1187.

Camacho-Collados, M. and F. Liberatore, 2015. A decision support system for predictive police patrolling. Decis. Support Syst., 75: 25-37.

Chen, H., W. Chung, J.J. Xu, G. Wang, Y. Qin and M. Chau, 2004. Crime data mining: A general framework and some examples. Computer, 37: 50-56.

Conrow, L., J. Aldstadt and N.S. Mendoza, 2015. A spatio-temporal analysis of on-premises alcohol outlets and violent crime events in Buffalo, NY. Applied Geogr., 58: 198-205.

De Zoete, J., M. Sjerps, D. Lagnado and N. Fenton, 2015. Modelling crime linkage with Bayesian networks. Sci. Just., 55: 209-217.

Dong, X.S., H.Z. Ma and Z. Yang, 2014. An Application of AHP and FAHP on the model prediction. Applied Mech. Mater., 687-691: 1641-1644.

FBI., 2004. Uniform Crime Reporting (UCR) Handbook. U.S. Department of Justice, Federal Bureau of Investigation, USA.

FBI., 2014. Reporting rape in 2013: Summary Reporting System (SRS) user manual and technical specification. U.S. Department of Justice, Federal Bureau of Investigation, Criminal Justice Information Services Division, USA.

Ferreira, J., P. Joao and J. Martins, 2012. Gis for crime analysis: Geography for predictive models. Electron. J. Inform. Syst. Eval., 15: 36-49.

Fredrick, O.R. and O. Patrick, 2012. Survey of data mining methods for crime analysis and visualization. Part 4: ICT and Legal Applications, pp: 221-226.

Gerber, M.S., 2014. Predicting crime using twitter and kernel density estimation. Decis. Support Syst., 61: 115-125.

Gorr, W., A. Olligschlaeger and Y. Thompson, 2003. Short-term forecasting of crime. Int. J. Forecasting, 19: 579-594.

Grubesic, T.H., 2006. On the application of fuzzy clustering for crime hot spot detection. J. Quant. Criminol., 22: 77-105.

Harris, R., 2012. Introduction to decision making, Part 1. VirtualSalt, June 9, 2012. http://www.virtualsalt.com/crebook5.htm.

Hooghe, M., B. Vanhoutte, W. Hardyns and T. Bircan, 2011. Unemployment, inequality, poverty and crime spatial distribution patterns of criminal acts in belgium, 2001-06. Br. J. Criminol., Vol. 51. 10.1093/bjc/azq067

Ismail, S. and N. Ramli, 2013. Short-term crime forecasting in Kedah. Proc.-Social Behav. Sci., 91: 654-660.

Jennings, W., S. Farrall and S. Bevan, 2012. The economy, crime and time: An analysis of recorded property crime in England & Wales 1961-2006. Int. J. Law Crime Justice, 40: 192-210.

Johnson, D., 2013. The space/time behaviour of dwelling burglars: Finding near repeat patterns in serial offender data. Applied Geogr., 41: 139-146.

Kaikhah, K. and S. Doddameti, 2006. Discovering trends in large datasets using neural networks. Applied Intell., 24: 51-60.

Keyvanpour, M.R., M. Javideh and M.R. Ebrahimi, 2011. Detecting and investigating crime by means of data mining: A general crime matching framework. Procedia Comput. Sci., 3: 872-880.

Krishnamurthy, R. and J.S. Kumar, 2012. Survey of data mining techniques on crime data analysis. Int. J. Data Mining Tech. Applic., 1: 117-120.

Ku, C.H. and G. Leroy, 2014. A decision support system: Automated crime report analysis and classification for e-government. Govt. Inform. Quart., 31: 534-544.

Law, J., M. Quick and P.W. Chan, 2015. Analyzing hotspots of crime using a bayesian spatiotemporal modeling approach: A case study of violent crime in the greater toronto area. Geograph. Anal., 47: 1-19.

Lee, I. and V. Estivill-Castro, 2011. Exploration of massive crime data sets through data mining techniques. Applied Artif. Intell., 25: 362-379.

Li, S.T., S.C. Kuo and F.C. Tsai, 2010. An intelligent decision-support model using FSOM and rule extraction for crime prevention. Exp. Syst. Applic., 37: 7108-7119.

Li, X. and M. Juhola, 2014a. Application of the self-organising map to visualisation of and exploration into historical development of criminal phenomena in the USA, 1960-2007. Int. J. Soc. Syst. Sci., 6: 120-142.

Li, X. and M. Juhola, 2014b. Country crime analysis using the self-organizing map, with special regard to demographic factors. AI Soc.: Knowledge Cult. Commun., 29: 53-68.

Liao, S.H., P.H. Chu and P.Y. Hsiao, 2012. Data mining techniques and applications-a decade review from 2000 to 2011. Expert Syst. Applic., 39: 11303-11311.

Malathi, A. and S.S. Baboo, 2011. An enhanced algorithm to predict a future crime using data mining. Int. J. Comput. Applic., 21: 1-6.

Malleson, N., A. Heppenstall and L. See, 2010. Crime reduction through simulation: An agent-based model of burglary. Comput. Environ. Urban Syst., 34: 236-250.

Malleson, N. and M. Birkin, 2012. Analysis of crime patterns through the integration of an agent-based model and a population microsimulation. Comput. Environ. Urban Syst., 36: 551-561.

Mande, U., Y. Srinivas and J.V.R. Murthy, 2012. An intelligent analysis of crime data using data mining and auto correlation models. Int. J. Eng. Res. Applic., 2: 149-153.

Marzbali, M.H., A. Abdullah, N.A. Razak and M.J.M. Tilaki, 2012. Validating crime prevention through environmental design construct through checklist using structural equation modelling. Int. J. Law Crime Justice, 40: 82-99.

Mohler, G., 2014. Marked point process hotspot maps for homicide and gun crime prediction in Chicago. Int. J. Forecasting, 30: 491-497.

Ngai, E.W.T., Y. Hu, Y.H. Wong, Y. Chen and X. Sun, 2011. The application of data mining techniques in financial fraud detection: A classification framework and an academic review of literature. Decis. Support Syst., 50: 559-569.

Nissan, E., 2012. An overview of data mining for combating crime. Applied Artif. Intell., 26: 760-786.

Noor, N.M.M., R. Astari, M. Norizan, M.S.M. Yazid and A.M. Lazim, 2011. A framework of decision support for crime forecasting in Malaysia. Proceedings of the 2nd European Conference for the Applied Mathematics and Informatics, December 29-31, 2011, Montreux, Switzerland, pp: 31-35.

Noor, N.M.M., A. Retnowardh, M.L. Abd and M.Y.M. Saman, 2013. Crime forecasting using ARIMA model and fuzzy alpha-cut. J. Applied Sci., 13: 167-172.

PMDU., 2010. Government Transformation Programme: The Roadmap. Percetakan Nasional Malaysia Berhad (PNMB), Putrajaya, ISBN: 9789671002605, Pages: 261.

Palocsay, S.W., P. Wang and R.G. Brookshire, 2000. Predicting criminal recidivism using neural networks. Socio-Econ. Plann. Sci., 34: 271-284.

Patel, P.C. and U. Singh, 2013. A novel classification model for data theft detection using advanced pattern mining. Digital Invest., 10: 385-397.

Phillips, P. and I. Lee, 2012. Mining co-distribution patterns for large crime datasets. Exp. Syst. Applic., 39: 11556-11563.

Ribaux, O. and P. Margot, 2003. Case based reasoning in criminal intelligence using forensic case data. Sci. Justice, 43: 135-143.

Rossy, Q. and O. Ribaux, 2014. A collaborative approach for incorporating forensic case data into crime investigation using criminal intelligence analysis and visualisation. Sci. Justice, 54: 146-153.

Roth, R.E., K.S. Ross, B.G. Finch, W. Luo and A.M. MacEachren, 2013. Spatiotemporal crime analysis in US law enforcement agencies: Current practices and unmet needs. Government Inform. Quart., 30: 226-240.

Saridakis, G., 2004. Violent crime in the United States of America: A time-series analysis between 1960-2000. Eur. J. Law Econ., 18: 203-221.

Shoesmith, G.L., 2013. Space-time autoregressive models and forecasting national, regional and state crime rates. Int. J. Forecasting, 29: 191-201.

Shrivastav, A.K. and Ekata, 2012. Applicability of Soft computing technique for Crime Forecasting: A preliminary investigation. Int. J. Comput. Sci. Eng. Technol., 3: 415-421.

Sieker, H., S. Bandermann, K. Schroter, M. Ost rowski and A. Leichtfuss *et al*., 2006. Development of a decision support system for integrated water resources management in intensively used small watersheds. Water Practice Technol., 1: 1-9.

Soh, M.B.C., 2012. Crime and urbanization: Revisited Malaysian case. Procedia-Soc. Behav. Sci., 42: 291-299.

Sukanya, M., T. Kalaikumaran and S. Karthik, 2012. Criminals and crime hotspot detection using data mining algorithms: Clustering and classification. Int. J. Adv. Res. Comput. Eng. Technol., 1: 225-227.

Tayal, D.K., A. Jain, S. Arora, S. Agarwal, T. Gupta and N. Tyagi, 2015. Crime detection and criminal identification in India using data mining techniques. AI Soc., 30: 117-127.

Wang, D., W. Ding, H. Lo, M. Morabito, P. Chen, J. Salazar and T. Stepinski, 2013. Understanding the spatial distribution of crime based on its related variables using geospatial discriminative patterns. Comput. Environ. Urban Syst., 39: 93-106.

Welsh, B.C. and D.P. Farrington, 2012. Science, politics and crime prevention: Toward a new crime policy. J. Crim. Justice, 40: 128-133.

Wu, J. and D. Wang, 2014. The research based on bayesian behavior recognition technology. Applied Mech. Mater., 543-547: 2167-2170.

Yan, Y.W., X.Z. Lu, J.X. Meng and Y.J. Lu, 2012. Prediction of geographical criminal's anchor point based on Bayesian-grid search. Adv. Mater. Res., 566: 604-607.

Zhou, F., B. Yang, L. Li and Z. Chen, 2008. Overview of the new types of intelligent decision support system. Proceedings of the 3rd International Conference on Innovative Computing Information and Control, June 18-20, 2008, IEEE, Dalian, Liaoning, pp: 267.