Modeling and Mapping Crime in Eastern Nairobi, Kenya

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Abstract. This working paper provides a description of the phases of my PhD study. Drawing on assumptions from various theories of environmental criminology, this study applies various crime mapping methodologies to observe geographic and temporal patterns of crime in the eastern part of the Kenyan capital city, Nairobi. This paper outlines the first completed phase which employs criminal geographic profiling to predict offender abodes, and also briefly identifies the next two phases of the study that involve spatio-temporal analysis and a regression modeling respectively. Results from the completed study have potential implications on the prediction and ultimate reduction of criminality, both within the Nairobi capital and also in other cities with similar spatial patterns.

Keywords: Crime; Point pattern analysis; Geographic profiling; Nairobi, Kenya

1 Introduction

Extensive infrastructural and technological development of many developing world cities is rapidly transforming the world into a single global village (Marquardt, 2013). A negative effect of this globalization has however been the accelerated criminality in major capital cities. Within the Kenyan capital of Nairobi, for example, crime poses numerous diverse consequences to the economic and social growth. The proliferation of suspects, dynamic modern offender tactics, and the persistent use of traditional methods by the law enforcement make crime investigation, prediction and prevention complex and hence resource intensive. Despite high crime reporting in many areas of developing countries, the adoption of computerized analysis to aid crime investigation remains conservative. This is to a large extent because crime-related information in many developing countries is not automated, but also because this information has previously remained available to crime mapping researchers. Recognizing the futility of combating the ever-dynamic modern criminal tactics with traditional methods, however, the law enforcement is increasingly liaising with researchers to devise new forms of understanding and representing the criminality problem.

Crime mapping complements a number of safety related analyses such as tactical and strategic crime analysis, intelligence analysis, operational analysis, criminal investigative analysis and administrative crime analysis (Ferreira, 2012). The former three influence security policy formulation while the last three are more concerned with the day-to-day reinforcement of law and order. Due to the features and characteristics of different rural and urban landscapes which pose major enticement or hindrance to crime occurrence, geography plays an important role to the mapping of crime. Until the 1970s crime modeling and mapping activities by the police, criminal and justice systems, and criminological researchers were hindered by technology. The field of geographic information science was not well established, and the geography of crime in particular was up until the late 1980s shunned (Peet 1975; LeBeau and Leitner 2011). A major turnaround occurred with the realization of the high potential for spatial techniques to map crime, and the 1990s witnessed dramatic increase in the diffusion of geographic concepts, tools and techniques for crime modeling and mapping in academic and applied criminal justice systems. Rudimentary crime analysis that comprised manual graphing of crime sites, review of criminal records, and using pin maps has since revolutionized to incorporate advanced spatial crime modeling with data mining and mapping tools (Ratcliffe 2010; Perry 2013). Comprehensive amounts of crime incidents which together with their associated location information and timestamps are accumulated in police database over time can now be used intelligently to reveal offending patterns. Criminal justice agencies have also in the recent years turned to environmental criminologists to provide theoretical explanations to the observed offending patterns and ultimately to develop solutions to five basic questions pertaining to crime:

i) Where does crime occur (areas with crime hotspots, type of location)?
ii) What crime is happening (e.g. drug sales, robbery, burglary)?
iii) When is crime happening (temporal details e.g. day of week, hour of day, season)?
iv) Who is committing crime (repeat offender traits and locations)?
v) Why is crime occurring (motive, attractors, inhibitors)?

Often differing in goal and context, various techniques from geographic information science commonly incorporate theories and technologies to provide answers to the “where” problem, and by extension to derive solutions to the other four problems. Offender-behavior mapping theories such as the routine activity theory (Felson, 1998), the rational choice theory (Cornish and Clarke, 1987, Clarke and Felson, 1993), the cognitive theory (Brantingham & Brantingham, 2008) the optimal foraging theory (Krebs, 1978) and the crime pattern theory (Brantingham & Brantingham, 1991) form a guideline to the algorithmic design of crime mapping systems. A discussion of these theories is however beyond the scope of this working paper. Statistics also provide a vital tool in the mapping of crime. When effectively used, statistics allow researchers to discover useful information, reduce criminality and maximize the utility of police resources. Each criminal event injects valuable information into the criminality puzzle, and the collective analysis of related events generates spatial patterns that analyze offender behavior. Spatial statistics therefore exploit Tobler’s (1970) rule of Geography which defines everything to be related to everything else and close entities to be more related than distant ones, and incorporate coordinate information about crime events to obtain geographic and temporal trends of offending variations.

The goal of this study is to develop crime mapping strategies which incorporate the most promising technical spatial analytics in order to derive a reference guide for law enforcement practitioners in combating criminality. With expectation of a wide application of results, the research aims to answer the following questions:

1. Can geographic profiling methods be empirically applied to accurately predict offender anchor points based on analysis of crime distributions?
2. To what level can spatio-temporal analysis of crime patterns identify crime clusters in space and time?

The study analyzes offending point patterns in order to model common offender behavior, and also to identify effective crime-prediction and investigation-focusing approaches. The area of project focus is Dandora-Kenya, an eastern-Nairobi area known for its alarmingly high rate of serial crime, with cases always making news headlines (e.g. Muhando, 2012; The Star, 2013; NTV-Kenya, 2013), investigative documentaries (e.g. Okari, 2013), topics in parliamentary discussions (Kenya National Assembly, 2010) and general web content (e.g. Wikipedia, TI-Kenya, 2008; Omondi, 2013). The study uses crime and other spatial data from Dandora and its surrounding environs which together forms the eastern part of Nairobi, and which lie within 10 kilometers of the Nairobi's central business district. The overall aim of the study is to enhance efficiency in criminal investigation by predicting crime occurrences, thereby reducing the time and effort expended in offender searches.

2 Applied Study Methodologies

The entire PhD study is phased in three stages, each applying a specific methodology towards solving the problem of crime mapping. This section will describe the different methods within the context of these phases.

2.1 Criminal Geographic Profiling

This phase models offender travel patterns and performs a comparative evaluation of different geographic profiling methods to test whether these methods can be empirically applied with the same level of success that has been previously witnessed in western countries. Criminal geographic profiling is a search prioritization strategy that analyzes the locations of already known crimes in order to predict the residence (or other anchor point) of a serial offender[1]. Spatial offender profiling methods are developed around the theories mentioned above, which model travel characteristics and the factors influencing target choices. Geographic profiling algorithms therefore take into account the offender’s ability to weigh the costs and benefits associated with a crime through careful premeditation, before an execution whose journey will often begin from home and is characterized by a non-offence buffer zone. The output is usually a probability surface with each cell depicting a distinct likelihood of offender residence. A dataset of 1,422 solved crimes constituting 346 series of 10 different crime types was used to compare five different probability statistics from geographic profiling (see Levine, 2009), alongside three centrographic statistics (the mean center, median center and center of minimum distance). Results show offenders in the study area to travel relatively shorter distances to crime than the distances demonstrated in studies from developing countries. These journeys are also more multi-directional, probably due to the use of footpaths as opposed to personal motor vehicles.

Strategy evaluation uses two basic measures; error distance, and search cost. Error distance measures the distance between the criminal's actual base and his predicted anchor point, evaluating a geoprofile’s accuracy and utility. Search cost computes the percentage of the offence domain that must be searched before finding the offender's anchor. The negative exponential function, a probability statistic, has been found to be the most accurate strategy in predicting offender anchor points. A typical probability surface generated with the negative exponential function is overlaid with output from centrographic statistics (Figure 1).

[1] An offender who has committed multiple crimes, with each crime committed at a different time

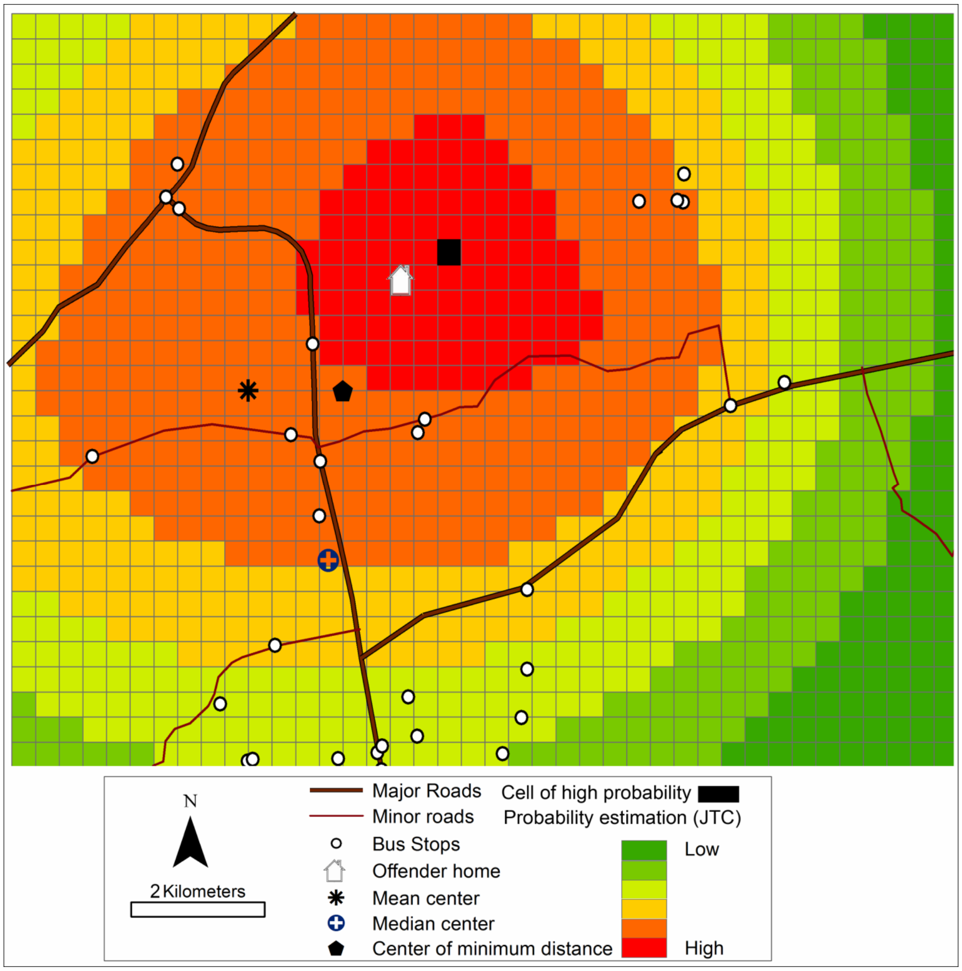

Fig. 1. Probability surface of the negative exponential journey to crime function

The function predicts a direct Euclidean distance of about 300m from the cell with the highest offender residence probability to the offender's actual home. This is more than double the precision of prediction by the centrographic statistics. The most important outcome of the study is the discovery that geographic profiling which has recorded substantial success in focusing high-profile criminal investigations in the western world can be applied in developing countries with the same effectiveness. Output from this study phase is currently undergoing the publication process.

2.2 Space and Time Crime Surveillance

This phase is ongoing and applies a mixture of time series analysis with kernel density estimation and the space-time permutation scan statistic (Kulldorf et al., 2011) to monitor patterns of crime reported during the time period between 01 January, 2009 and 31 December, 2010. The underlying hypothesis is that crime events are seasonal and vary by crime type. For the purpose of analyzing crime patterns in time series to observe seasonal crime variation the crime data are aggregated based on days of the week and month, as well as the months of the year. Kernel density estimation places a symmetrical surface, called the kernel function, over each event and then sums-up the values of all surfaces onto a regular reference grid that is superimposed over the entire observation area. A typical symmetrical kernel function will fall off with distance from each event at a rate that is dependent of the shape of the kernel function and the chosen bandwidth.

The spatio-temporal scan statistic uses multiple overlapping cylinders to define the scanning window, with the base of the cylinder representing the area under observation, and the height representing the time period in days. Using Monte Carlo hypothesis testing, *p*-value computation justifies the statistical significance, and a value smaller than the set significance level (mostly 5 percent) determines cluster abnormality within an offence distribution. Space-and-time clustering extends spatial clustering methods by adding the element of time into the analysis, thereby identifying the clusters in three-dimensional space. This new analysis can be used to retrospectively analyze historical data, as is the case with the current study, as well as to prospectively survey and predict crime outbreaks through ongoing analysis of day-to-day data. The expected result is the identification of crime clusters in space and time, and subsequently the identification of early crime-detection surveillance.

2.3 Future Crime Prediction

The last study phase will apply regression analysis to model the relationship between the socio-economic factors in the study area and crime events. The expected result is identification of patterns that will enable prediction of future crime levels.

3 Conclusion

By making use of the available crime data and appropriate spatial and temporal methods in crime mapping, this study aims to observe crime and offender dynamics, and the factors affecting crime negatively and positively. The methods used for the study have practical implications due their high relevance to policy and wide applicability for law enforcement in other areas.

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