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A Decision Support System for predictive police patrolling

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ABSTRACT

In the current economic climate, many police agencies have reduced resources, especially personnel, with a consequential increase in workload and deterioration in public safety. A Decision Support System (DSS) can help to optimize effective use of the scarce human resources available. In this paper we present a DSS that merges predictive policing capabilities with a patrolling districting model, for the design of predictive patrolling areas. The proposed DSS, developed in close collaboration with the Spanish National Police Corps (SNPC), defines partitions of the territory under the jurisdiction of a district that are efficient and balanced at the same time, according to the preferences of a decision maker. To analyze the crime records provided by the SNPC, a methodology for the description of spatially and temporally indeterminate crime events has been developed. The DSS has been tested with a case study in the Central District of Madrid. The results of the experiments show that the proposed DSS clearly outperforms the patrolling area definitions currently in use by the SNPC. To compare the solutions in terms of efficiency loss, we discuss how to build an operational envelope for the problem considered, which can be used to identify the range of performances associated with different patrolling strategies.

1. Introduction

In this paper, we propose a Decision Support System (DSS) for the implementation of a new paradigm of predictive police patrolling for the efficient distribution of police officers in a territory under the jurisdiction of a police department, with the aim of reducing the likelihood of criminal acts. This DSS, called the Predictive Police Patrolling DSS (P^3-DSS), has been developed in collaboration with the Spanish National Police Corps (SNPC).

Intuition has always been a fundamental part of police work [39]. Knowledge in the field by experienced managers of public security has proven to be a useful weapon against crime. In most police departments, this experience-based system remains unchanged. However, police intuition may not be taking into account all the factors influencing the evolution of crime. Historically, criminology has shown great interest in the identification of areas with a higher rate of criminal activity [5]. It has been proven that studying historical data allows identifying places where crime tends to agglomerate. Therefore, making use of historical information is fundamental for decreasing crime, as we know that crime has greater chances of happening when there are no security measures and a motivated criminal encounters an appropriate objective [48,49]. Consequently, in the last decade, predictive policing measures have been developed, with different levels of sophistication, with the aim of providing an analysis of the evolution of crime in a territory. More recently, both academics and practitioners, such as the RAND corporation and the National Institute of Justice of the United States (NIJ), have recognized the need for taking a step forward and developing explicit DSS to provide help to decision makers in law enforcement agencies [38].

1.1. The Predictive Police Patrolling DSS (P^3-DSS)

In Spain, the security of towns is the responsibility of the SNPC, usually sharing a territory with other local security forces. The SNPC is an armed institution of a civil nature, dependent on the Spanish Ministry of Home Affairs. Among its duties are keeping and restoring order and public safety and preventing the commission of criminal acts. The SNPC is one of the country's most valued institutions, and is at the global forefront of the fight against crime, with the aim of constant innovation. Under the current system, the distribution of agents is determined by the inspectors that coordinate the service during a particular shift. Their experience, accompanied by preliminary information, such as a summary of the criminal activity of the last days, leads them to decide on the allocation of policemen in a whole district.

The socio-economic context in recent years in Spain is that of a severe crisis that has reduced the number of police officers available to the SNPC. Therefore, designing the distribution of agents in a territory has become a complex task, and the lack of personnel can result in a lowered level of security and, as a consequence, in an increased level of crime. In order to continue providing the same level of security to

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the citizens of Spanish cities, the SNPC is taking steps to increase its competitiveness, such as the development of a DSS to assist decision-making processes in matters of public security in Madrid, with the intention of applying this methodology to other cities. The seminal work of [47] showed that making use of optimization models results in a reduction of the level of subjectivity present in this kind of decision-making, an improvement in the quality of the decisions, and an increase in the level of satisfaction of the policemen involved.

This article has made the following contributions to the literature on DSS for public security management. First, we illustrate the pilot study that was undertaken in collaboration with the SNPC to develop a DSS for the implementation of a predictive police patrolling paradigm: the P^3-DSS. This DSS provides predictive policing capabilities for forecasting the distribution of crime risk in a territory, as well as an optimization system that exploits this information to distribute agents in the best possible way, according to the preferences of the decision maker. To the best of the authors' knowledge, this is the first DSS for public security managers that combines predictive policing techniques to support the allocation of human resources. Furthermore, we present a methodology for the temporal and spatial description of crime events in which the time and the location of the incidents are indeterminate. In fact, the exact time and location of occurrence of an incident is often not known to the victim or the police. As an example, a victim of a pickpocket will often realize that he/she has been robbed after a certain time, therefore making it impossible to determine precisely when and where the crime occurred. Previous works on the subject have dealt exclusively with temporally indeterminate crimes [30] and, to the best of the authors' knowledge, no treatment for spatial uncertainty has been proposed in the literature. Moreover, we propose a novel algorithm to define the operational envelope for the specific shift under study. The operational envelope is a powerful tool for identifying the range of impacts of different patrolling strategies and to quantify possible efficiency losses of suboptimal plans. Finally, to test our DSS, we present a case study of the Central District of Madrid. This same methodology can be easily extended to any district. Additionally, we provide some insights into the patrolling strategies produced by the DSS and compare their performance to the current patrol sector configurations adopted by the SNPC.

The reminder of the article is organized as follows. In the next section we present the current state of the art of predictive policing. This part also examines the theoretical background and current research into the Police Districting Problem (PDP) and focuses on the existing DSS for efficient policing. In Section 3, the structure of the proposed DSS, called P^3-DSS, is given. Next, in Section 4, we present the operational envelope, its application in the evaluation of patrolling configurations, and an algorithm for its computation. In Section 5 we apply the P^3-DSS to a real case study of the Central District of Madrid. The article concludes with a summary of the main findings of this research and some possible future lines of research to be explored.

2. Related work

In this section, a review of the most relevant contributions to the literature is presented.

2.1. Predictive policing

The term predictive policing is relatively recent and refers to the application of quantitative techniques to foretell where crimes will take place in the short-term future. The National Institute of Justice (NIJ) defined it as taking data from disparate sources, analyzing them, and then using the results to anticipate, prevent, and respond more effectively to future crimes [36]. This technique is based upon advances in criminology, such as Hot Spot theories [43,54,53], and studies of the ecology of crime [7,8]. Statistics based methods have been used since the release of CompStat in 1994, but it was only a few years ago that complex mathematical algorithms have been developed to address this problem in the most profound way. CompStat combined Geographic Information System (GIS) and crime mapping techniques to identify areas of high crime intensity. The importance of measuring the occurrence of crimes in the police districts and keeping track of the actions of the police managers for decision-making was proven by Weisburd *et al.* [55]. This topic was opened to different approaches by the International Journal of Forecasting, which published a special issue on crime forecasting in 2003 [24].

Years later, researchers at UCLA started a new approach to the investigations of crime agglomerations, modeling the dynamics of crime hotspots and determining the parameter values that lead to the creation of stable hotspots [45]. In a subsequent study, they used amplitude equations to study the development of crime hotspot patterns [44] and self-exciting point processes [35]. Also, they mathematically proved that there were different types of hotspots, even though they seemed similar at first sight. This breakthrough was further developed using Levy Flight models by Chaturapruek *et al.* [14]. More recently, Zipkin *et al.* [58] introduced a police behavior component aiming at suppressing hotspots of criminal activity. In this model, the police deployment adapts dynamically to changing crime patterns, making criminals modify, to a certain degree, their awareness and their criminal actions.

Probably the most ambitious predictive policing project so far made use of the algorithms created by Brantingham and Mohler, along with LAPD Captain Sean Malinowski. With three years of data, and focusing on three types of crime in particular (i.e., burglary, automobile theft, and theft from automobiles), the algorithm points out areas of likely crime incidence. The first analyses have shown a reduction of property offenses where this methodology has been implemented, reporting considerable reductions in serious violence crimes in the treatment cities and areas relative to comparison cities and areas. Another experiment of predictive policing was implemented in Santa Cruz, where predictive maps based on risk percentages were given to security managers. The use of these maps resulted in a 19% drop in burglaries [21].

Another line of research that has been widely applied in practice has focused on Risk Terrain Modeling (RTM) [11]. According to its creators, RTM is "an approach to risk assessment in which separate map layers representing the influence and intensity of a crime risk factor at every place throughout a geography is created in a Geographic Information System (GIS). Then all map layers are combined to produce a composite "risk terrain" map with values that account for all risk factors at every place throughout the geography" [10]. RTM has also been proposed as a methodology for the identification of risk clusters and the distribution of police resources [30].

A number of models making use of methodologies other than hotspot and RTM have been presented in the academic literature. Xue and Brown [56] and Smith and Brown [46] developed a spatial choice model and represented criminal events as point processes combining discrete choice techniques and data mining. They used this approach to predict the spatial behavior of criminals, comparing it with existing hotspot analyses. Furtado *et al.* [22] model criminal behavior by using ant-inspired systems, trying to discover strategies for efficient police patrolling that take into account the dynamics of the criminals. Wang and Brown [51] used a spatio-temporal analysis for modeling criminal incidents, making use of a variety of data types, such as spatial, temporal, geographic, and demographic data. In a subsequent paper, Wang *et al.* [52] extended this prediction model to include information proceeding from social network posts. A similar approach is proposed by Gerber [23], finding that by combining historical crime records with Twitter data from users in a specific geographic area, the prediction performance improves for 19 of 25 crime types. Finally, Chen *et al.* [15] applied spatio-temporal analysis methods to investigate patterns of offenses against property.

2.2. The Police Districting Problem (PDP)

District design can be seen as the problem of grouping the elementary units of a given territory into larger districts, according to their relevant attributes. Depending on the problem faced, the attributes