Modelling Police Patrol Routing as Min-Max Postmen Problems

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Summary

This paper deals with the challenges in police patrol routing when multiple patrollers from different police stations. The patrollers should cover each given site at least once, and they should cover balanced route lengths to avoid discontentment and possible work overload. This routing problem is formulated as a Min-Max Multiple Centre Rural Postman Problem here, which is proposed for the first time. This provides a conceptual base toward finding a suitable routing algorithm for police patrol.

KEYWORDS: patrol route design, site coverage, route balance, min-max, arc routing

1. Introduction

Police patrolling plays an important role in public safety. It serves to enhance the criminals' perceived risk of detection, thus preventing potential crimes. Moreover, the visible police presence would increase the public's certainty of punishment and the public trust and confidence in policing (Cheng et al. 2016).

Effective patrolling requires finding optimum routes for the patrollers. The common objective is to cover a set of selected important sites by dispatching a group of patrollers. The patrol route design problem falls into two categories of either repeated monitoring or single traversal. The major difference between these two is the frequency of visit. In repeated monitoring, the sites are visited recurrently during a period. This problem can be solved by a real-time patrol routing strategy (Chen et al. 2017). In contrast, in single traversal problem, each site has to be visited at least once. This scenario is realistic when sites are many and patrol forces are limited. This paper deals with routing police patrol in the single traversal scenario.

The route design for police patrol may become complex because of several reasons. Firstly, important sites are not evenly distributed in the area. The area with higher density of sites naturally needs more coverage. Secondly, patrollers may start patrol from different stations, which make the route design more difficult. Thirdly, the complexity is increased even further when balance among routes is taken into consideration. Patrolling of the area should be evenly distributed among patrollers to avoid dissatisfaction and work overload (Willemse & Joubert 2012). One possible way to guarantee the even workload distribution is to minimise the longest route among patrollers.

To our knowledge, this problem is proposed for the first time, and no literature on this subject is available. A similar patrol route design problem is solved by Willemse and Joubert (2012), which is the routing of security guards. The problem deals with similar objectives such as monitoring the environment of the area and the balanced route lengths among guards. However, it assumes that all guards start and end their journey from the same station, which is not applicable to police patrol, as

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patrollers start from different police stations.

In this paper we describe the constraints and objectives of designing the police patrol routes, and show that this problem can be modelled as the Min-Max Multiple Centre Rural Postman Problem.

2. Problem definition and formalisation

Figure 1 shows a map of important edges and the distribution of police stations in the London Borough of Camden. These edges are crime hotspots, which are segments that have the highest crime density and that accumulatively cover 5% of the total segment length. Note that the important edges are not limited to crime hotspots, and can be selected by other criteria. In a patrolling shift, a group of foot patrols are dispatched to cover the area and especially the crime hotspots, to guarantee public safety. Each crime hotspot needs to be traversed at least once by a group of foot patrol. Each foot patrol starts and ends their patrolling in the same station, and distinct patrols may belong to different stations. Foot patrols may traverse the roads in any direction.

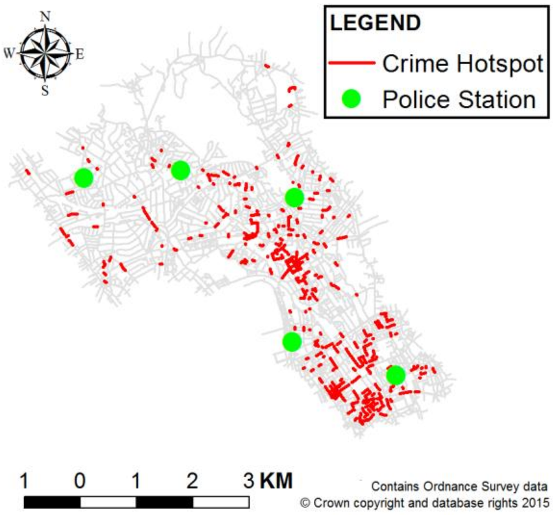

Figure 1 Crime hotspot map in Camden

In this patrolling task, the main objectives are two-folded: to cover each crime hotspot at least once, and to balance the length of patrolling routes among patrollers. Informally, the problem can be defined as: *given a set of important arcs and a group of patrollers that start from different stations, try to design the routes for each patroller in order to traverse each important arc at least once and to minimise the length of the longest route.*

This routing problem can be modelled as a node routing problem or an arc routing problem (ARP). As patrollers have to traverses the road streets in patrolling to increase coverage, an ARP is more suitable for this task.

The aim of an ARP is defined as "determining a least-cost traversal of a specified subset of a graph with certain constraints" (Eiselt et al. 1995). One classic ARP is the Rural Postman Problem (RPP), which requires only a subset of edges have to be traversed. The general RPP is NP-hard (Lenstra & Kan 1976), and a heuristic solution procedure to solve the RPP was presented by Christofides et al. (1981), with the approximation ratio of 2/3.

The classic RPP only involves one postman. It has been expanded to include multiple postmen. The objective is also adjusted, either to minimise the total length of all routes or to minimise the length of the longest route. The latter is the min-max RPP (Willemse & Joubert 2012). The min-max RPP has been studied and solved by several researchers (Arkin et al. 2006; Benavent et al. 2009; Willemse & Joubert 2012). Min-max RPP assumes all routes start and end in the same station. This can be generalised to the multiple-station or multilple-centre situation, i.e. postmen may start from different centres. The more general and realistic problem is called Min-Max Multiple Centre Rural Postman Problems (MMMCRPP). To our knowledge, this problem has received no attention.

In police patrol, as patrollers start from different stations, the police patrol route design problem is modelled as a MMMCRPP. Table 1 gives the details of the MMMCRPP.

Table 1 Formulation of MMMCRPP

Item	Content
Input	**k**: number of postmen. **L**: maximum length of each route. **G = (V, E, R)**: an undirected graph. V: nodes; E: undirected edges; R: a subset of E. **D**: list of centres. D = {D1, D2, ..., Dk}. The centres may be different.
Constraint	**Max route length constraint**: each route should be no longer than a threshold value. **Closed tour constraint**: each postman should start and end their tour in the specified centre. **Traversal constraint**: each edge in E should be traversed at least once.
Output	**RT**: a list of routes, which is called a solution. RT={RT1, RT2, …, RTk}.
Objective Function	To minimise the length of the longest route of RT.

3. Conclusion

This paper demonstrates how the design of police patrol routes can be modelled as the Min-Max Multiple Centre Rural Postman Problem. Next step of this research is to design the solution algorithm and the corresponding algorithm evaluation. It is also worth noting that the MMMCRPP is not limited to the policing scenario. Other possible applications include the routing of parcel delivery and power line inspectors. In the future, it would be interesting to investigate this model in other fields as a route planning tool.

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5. Biography

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