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Police officer dynamic positioning for incident response and community presence

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Police Officer Dynamic Positioning for Incident Response and Community Presence

Using Maximum Demand Coverage and Kernel Density Estimation to Plan Patrols

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Abstract: Police Forces are under a constant struggle to provide the best service possible with limited and decreasing resources. One area where service cannot be compromised is incident response. Resources which are assigned to incident response must provide attendance to the scene of an incident in a timely manner to protect the public. To ensure the possible demand is met maximum coverage location planning can be used so response officers are located in the most effective position for incident response. This is not the only concern of response officer positioning. Location planning must also consider targeting high crime areas, hotspots, as an officer presence in these areas can reduce crime levels and hence reduce future demand on the response officers. In this work hotspots are found using quadratic kernel density estimation with historical crime data. These are then used to produce optimal dynamic patrol routes for response officers to follow. Dynamic patrol routes result in reduced response times and reduced crime levels in hotspot areas resulting in a lower demand on response officers.

1 INTRODUCTION

Police forces must operate to a high efficiency to ensure the safety of the public and property with the limited budget available. In many countries the police are currently facing budget cuts and hence this is of increasing importance. One area where the public's safety is very reliant on efficient use of resources is incident response. This is where a situation is brought to the attention of the police dispatchers and it is determined that an officer presence is required at the situation. An officer out of those assigned to response is then allocated to the situation. An example of this could be when a burglary is reported to be currently taking place. In this situation resources will be allocated to attend the incident with the aim of apprehending the criminal. The time taken to reach the scene of the incident can affect the outcome of the situation. In the UK there are target response times which are dependent on the incident severity and whether it occurs in the city or rural environment. To increase the chances of an officer being able to respond to an incident within these response times their positioning whilst not attending an incident can be optimized. The key factors to consider when positioning officers are:

- predicted demand coverage
- presence in areas where crime levels are high
- visibility.

The first key factor requires the officers, not currently attending an incident, to be positioned to give the highest possible demand coverage. Hence this aspect of positioning is considered as a maximum coverage location problem, using an advancement of the double standard model used previously for ambulance positioning (Gendreau et al., 1997). The method varies from the original to allow the response time restrictions for both city and rural areas to be considered. Though demand coverage is a major concern it is not the only concern when positioning police officers. It has been shown that a police presence in areas of high crime, hotspots, can reduce crime in that area (Smallwood, 2015). The visible presence of a police officer also increases the public's feeling of safety. Due to the need to visit hotspots and visibility requirements police officers cannot be positioned by only considering the ideal response location. Hence in

this work a method of dynamic patrol route planning is developed, that takes into account demand coverage, hotspots and visibility to determine the most efficient route for officers to take when patrolling. This model of patrol planning also considers those response officers not presently available to patrol by removing them from the directed patrol routes whilst still considering them with regards to demand coverage.

The current method of directing patrol routes in the UK is through informing officers of waymarker locations, which are areas of concern, during a briefing before a shift. They are asked to visit these and stay within the defined waymarker boundaries for a set period of time, i.e. 15 minutes, when possible. They are not advised when to do this, where other officers are and hence are not considering demand coverage. This research demonstrates a method of advising officers on where to travel in real time when not attending an incident.

This research address an issue experienced by many police forces and has benefited from collaboration with Leicestershire police in the UK. Due to this collaboration Leicestershire has been used as a case study. Processes may vary slightly between forces but the tool will still be applicable.

The remainder of this paper is broken up as follows. Section 2 gives background to the project through looking at relevant research. Section 3 defines the problem to be addressed and aspects to consider. Section 4 describes the maximum coverage location problem to be solved. Section 5 shows how crime analysis is performed using quadratic kernel density estimation and how the crime data is displayed using thematic mapping. Section 6 details how the location problem is solved using a tabu search heuristic. Section 7 describes the routing process between hotspots. Section 8 contains the results of solving the problem and finally section 9 concludes the paper.

2 LITERATURE REVIEW

Location planning has already been heavily researched in many areas including ambulance positioning. These applications are generally looking at stationary locations. A maximal covering location problem (MCLP) is used to find the optimal location for ambulances (Daskin and Stern, 1981). This study is relevant to the police demand coverage problem but does not consider the two time restrictions required in police coverage and does not consider that repositioning is required. The MCLP problem is advanced to consider two time standards and the different levels of demand coverage required in the double standard model (Gendreau et al., 1997). This does not consider the two time restrictions required by the police. Further studies also considers the MCLP but considers repositioning when an ambulance is sent to an incident (Mandell, 1998). The study also considers the availability of the servers and two different servers. This study is relevant when considering the conditions of moving officers but does not consider the different level of coverage required and that police should not revisit bases within a certain time.

Operation Savvy (Smallwood, 2015) is a police operation carried out by West Midlands Police and Cambridge University to investigate the effect of directed patrols on crime hotspots. These directed patrols consisted of police community support officers (PCSOs) visiting the epicentre of a hotspot for fifteen minutes, three times at prime time, which is between 3pm and 10pm Wednesday to Saturday. To form the hotspots demand data from two years was used in a 150m radius. The hotspots focused on in this study are anti-sociable behaviour (ASB), burglary, criminal damage, theft and vehicle crime. Patrols were stepped up in 40 hotspots and 40 hotspots were kept as controls. The results of this study showed that in the high and medium crime level experimental hotspots there was a noticeable reduction in all crime types and anti-social behaviour. Further results on the communities trust and confidence in the police is to be examined by a survey. This study proved the effectiveness of directed patrol routes but only used this to direct PCSO patrols at certain times of day and demand coverage was not considered.

A tool, GAPatrol, to help police managers plan patrol routes is proposed in (Reis et al., 2006). In this study multiagent-based simulation assists in the design of police patrol routes. The simulation finds crime hotspots and plans routes with better coverage in these hotspot areas. Hence the routes are planned with the single aim of reducing crime levels and do not consider demand coverage for incident response.

The patrol routes of state troopers concerned with the prevention of traffic incidents has been explored (Li and Keskin, 2013). The aim of the study is to determine the best locations for temporary stations and increase the effectiveness of patrols by increasing visibility in time periods where high levels of crime have been experienced whilst minimizing associated costs which include price of state troopers, travelling costs and station fees. The

problem to be solved is similar to a multi-depot, dynamic location and routing problem.

A previous study on planning patrol routes based patrol routes on giving each road a crime rating and visiting those with the highest costs whilst also keeping cost of travel low (Chawathe, 2007). This study does not consider demand coverage for incident response and also only considers one police unit at a time which is not practical. In reality there are many units and where each of these units are patrolling effects the other units.

An alternative study on patrol routes uses ant colony algorithms along with Bayesian decision tool to plan patrol routes (Chen et al., 2015). The ant colony aspect relates to the history of patrols being tracked by the drop of virtual pheromone and its decay. This is a good method of stopping repeat hotspot visiting within short spaces of time whilst also tracking when another visit is required. The downfall of this study is that it doesn't consider coverage for incident response.

These previous studies help develop the idea of a dynamic routing problem addressed in this research. Once the problem is formulated a method of Tabu search is considered to solve the problem using MATLAB. Tabu search allows the search area to be narrowed down to give a solution in a shorter computational time, which is required in the fast paced dispatch process.

Hotspot mapping is a means of analyzing historic crime data to predict future crime patterns. This is possible as crime is not random. Crime follows patterns due to environmental influences effecting criminal's decisions (Kennedy et al., 2011). Crime mapping is widely used within the police and law enforcement agencies. There are many different methods including point mapping, spatial ellipses, thematic mapping and Kernel Density Estimation. There have been many studies determining the best method of hotspot mapping. A study by (Chainey et al., 2008) identified Kernel Density Estimation as the best method for predicting future crime locations. Hence it is the method which will be used in this study.

3 PROBLEM FORMULATION

A response officer's main duty is to provide emergency response to incidents of high severity. Responding to incidents takes up the majority of their time and there is limited time to patrol. When there is time to patrol these patrols must be directed efficiently. Those officers whom require patrol direction are those which are not currently attending an incident. The problem investigated is improving the efficiency of these patrol routes by giving them direction in real time. This direction is based on keeping good demand coverage between all the response officers and being visible in problem areas, hotspots. This will keep response times low and in the process deter crime from hotspots.

Response officers operate in units as some are paired to create double crewed vehicles hence the entities considered are response units. When a response unit is free to patrol the location to patrol is calculated using the processed formed in this research. The chosen location is then conveyed to the response unit as simple instructions. These instructions include time to spend at the location and what to look for, it assumed the unit will take the quickest route to this incident hence directions are not necessary. When they have attended the hotspot for the appropriate length of time this hotspot is marked as visited and if required a new hotspot location is assigned to the response unit. As more response units become free they are allocated hotspots. If incidents arise within the patrolling time the response to incident will take priority.

When solving the problem there are some constraints to be considered regarding policing standards and processes. Leicestershire Police requires that in an emergency situation a unit should attend the incident within fifteen minutes, which is taken to be t_C, in heavily populated areas such as cities and towns. In sparsely populated areas such as rural areas the response time should be within twenty minutes, which is taken to be t_R. The area can then be divided into areas with a node at the centre. Hence a node i is considered covered if the following conditions are met:

- when considering a town/ city a unit must be located within t_C of node i
- when considering a rural area a unit must be located within t_R of node i

Taking the distance which can be travelled within t_C to be r_1 and within t_R to be r_2 where $r_1 < r_2$ (Mandell, 1998).

This is a spatial problem which requires a region to be used for modelling. Data from OpenStreetMaps (© OpenStreetMap contributors, 2015) is used to form a directed graph of the roads in Leicestershire within MATLAB. The road map formed is shown in figure 1.

The problem formulated is now considered as a MCLP using hotspots as possible nodes to locate response units.

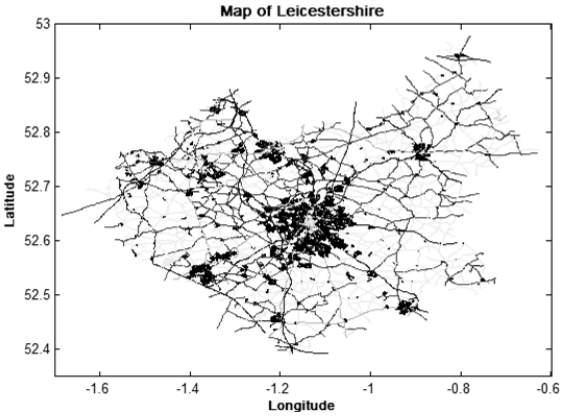


Figure 1: Road map of Leicestershire

4 MAXIMUM COVERAGE LOCATION PROBLEM

Demand coverage is a measure of how well response units are able to cope with possible emergency response demand. This can be determined by predicting demand using historical incident data and whether an officer can reach the demand location, node i, within the recommended response time. Nodes are a point of reference to measure demand from, they can be a point on a street or in reference to an area.

A variation of the double standard model is used to find maximum police coverage for a given number of officers (Gendreau et al., 1997). This method is suitable as it considers two time standards and also allows different levels of coverage, k, to be considered. This is necessary because areas with high levels of demand are not sufficiently covered by one response unit. k allows the level of response units required to consider a region as covered to be set. The objective function for this is equation (1) which aims to maximize coverage. The demand points are represented by the set $V = \{v_1, v_2, \dots, v_n\}$ and the demand at these points is d_i. x_i^k is a binary variable which equals 1 if v_i is covered a minimum of k times within the radius r_1 and 0 otherwise. Where k is the number of units which are in range to reach node i.

$$\text{Maximize} \sum_{i \in V} d_i x_i^k \qquad (1)$$

This objective function has been adapted here to apply to the police positioning problem. The adaption is necessary to account for the recommended response times for city and rural areas. Equation (2) accounts for city and rural response guidelines. In this equation ${}_1x_i^k$ is a binary variable which equals 1 if v_i is covered a minimum of k times within the radius r_1. ${}_2x_i^k$ is a binary variable which equals 1 if v_i is covered a minimum of k times within the radius r_2. C and R are binary variables which equal 1 if node v_i is in a city or rural area.

$$\text{Maximize} \sum_{i \in V} \left(d_i \, {}_1x_i^k C + d_i \, {}_2x_i^k R \right) \qquad (2)$$

The objective function results in the total demand covered at least k times within the required emergency response distances, r_1 or r_2 depending on its location. It is subject to the constraints:

$$\sum_{j \in W_i^k} y_j \geq 1 \quad (i \in V) \qquad (3)$$

$${}_{1,2}x_i^{k+1} \leq {}_{1,2}x_i^k \ (v_i \in V) \qquad (4)$$

$$\sum_{j \in W} y_i = p \qquad (5)$$

$${}_1x_i^k, {}_2x_i^k \in \{0,1\} \ (v_i \in V) \qquad (6)$$

$$C, R \in \{0,1\} \qquad (7)$$

$$C + R = 1 \qquad (8)$$

When considering response unit positioning $W = \{w_1, w_2, \dots, w_m\}$ represents the set of possible locations, these are decided by the hotspots found from incident analysis. y_j shows the number of resources located at j. The total number of units available is taken to be p and this is determined by the number of officers on shift with an available status at that time, whether they are single or double crewed and their availability. These constraints also differ from the original double standard model due to the different priorities of the police (Gendreau et al., 1997). The problem will still aim to cover all demand within at least r_2 which is taken into account by constraint (3). Constraint (4) states that node i can only be covered k+1 times if it is covered at least k times. Constraint (5) ensures that the sum of all the officers at each point W is equal to p. Constraint (6) and (7) ensures ${}_1x_i^k$, ${}_2x_i^k$, C and R are binary values. Finally constraint (8) states that either C or R must equal 1, but never both at the same time.

When solving the objective function above there are rules on where each officer can be placed due to their status and attached station. These are:

1. An officer can only move if its status is available (they are not attending an incident, in custody, on a break, etc.).
2. An officer only counts as covering an area if they are free to attend an incident, this includes officers who are available or attending an incident more minor than an emergency incident.
3. The distance from their base police station must be less than maximum displacement from their station allowed $r_W \leq r_s$, where r_W is the distance from the base police station to the possible location where an officer is required and r_s is the maximum distance an officer is allowed from their base station determined by the police force.

Rule 1 is just the condition that a police officer must be available before moving them. In rule 2 an officer is counted as covering an area if attending a grade 2 incident because if necessary they can leave such an incident to respond to an emergency incident but they cannot be moved unnecessarily. Hence they are not moved when solving for maximum coverage. Rule 3 ensures that officers do not move too far from their base police station. Each officer has an attachment to a particular police station and even though most police forces operate as boundaryless within their area it is not efficient to move an officer too far away from their associated station due to their journey back at the end of a shift.

When applying this approach to the ambulance location problem the possible nodes (W) where they can be located are bases, such as car parks and service stations. For the police it is more important to be based in hotspot areas where they are a deterrent to further crime.

5 INCIDENT MAPPING

Location is a very important factor when analyzing crime as repeat area targeting is more common than repeat offenders. Crime mapping is used to show where crimes occur; this allows the movement of crime over time to be analyzed. A study previously discussed (Reis et al., 2006) showed that crime is not evenly distributed but forms patterns due to the habits of criminals. Figure 2 shows the crime spread through Loughborough (a small town within Leicestershire) by the numbers in grey circles. It demonstrates the uneven distribution of crime, for example the town centre has a high level of crime at 119 incidents (Police UK, 2015). Crime analysis identifies these patterns which is the first step in reducing crime levels. Crime analysis is vital in the planning of patrol routes as routes should be directed to visit areas of higher than average levels of crime, called hotspots.



Figure 1: Crime distribution

Finding hotspots, determining the causes and responding to the results to reduce crime in the areas identified is referred to as problem oriented policing. Crime analysis has been in police forces for a long time, beginning with a map with pins in to represent crimes, developing to the same concept on a computer. It has been proven that focused patrols depending on these hotspots can assist with the prevention of crime (Smallwood, 2015). Currently police forces have a crime analysis team to look into crime patterns and computer programs to determine where high levels of crime occur.

Before crime can be analysed it requires filtering to pick out the data which is relevant to the problem and to discard bad data. This is described in section 5.1. Once it has been filter a means of analysing it is required which is done using quadratic kernel density estimation in section 5.2.

5.1 Incident Data Analysis

Data analysis is required to filter the incidents/crimes down to those relevant to police patrolling. The crimes and incidents considered are those where the presence of an officer can help deter them. These include:

- anti-social behavior
- theft
- vehicle crime
- burglary in dwelling and other
- criminal damage.

Incidents in certain places should be excluded from the analysis as they also cannot be prevented by the presence of an officer patrolling on the streets, these places include:

- clubs or bars
- shopping centers
- hospitals.

There are some incidents on record which may cause anomalies to the hotspot locations this is cases such as incidents mapping to a default area when the correct location has not been given. These are also filtered out before analysis of crime data.

Crime levels change depending on day, time of day and season. Hence it is not accurate to find general hotspots. Data is separated into Sunday-Thursday and Friday – Saturday and also into day, evening and night as well as seasonality. Hotspot analysis is then carried out separately using only data from the allocated time period. As hotspots change with time the possible locations to position officers (W) vary.

5.2 Kernel Density Estimation

Kernel Density Estimation is a method of spatial analysis for crime mapping which allows complex point patterns to be simplified to assist in the identification of hotspots. This method is superior to other crime mapping methods as it is not limited by strict boundaries such as beat boundaries. Beat boundaries are predefined areas, such as a town, which an officer has to patrol. Using boundaries can result in some hotspots which cross the boundary not being identified. Kernel Density Estimation uses grids however also considers the areas surrounding the grid cell, by using kernels, to allow the surrounding area to influence the intensity of crime within the cell.

Quadratic kernel density estimation involves overlaying a grid onto the map and visiting each grid cell to preform kernel density estimation. Figure 3 shows how quadratic kernel density estimation is performed and the process is then described below.

Kernel density estimation finds the points at which crime incidents have occurred within the predefined bandwidth boundary and determines the influence each of these crimes has on the intensity of crime in that area using equation 9 (Gatrell et al., 1996).

$$\hat{\lambda}_\tau(s) = \sum_{d_i \le \tau} \frac{3}{\pi\tau^2}\left(1 - \frac{d_i^2}{\tau^2}\right)^2 \qquad (9)$$

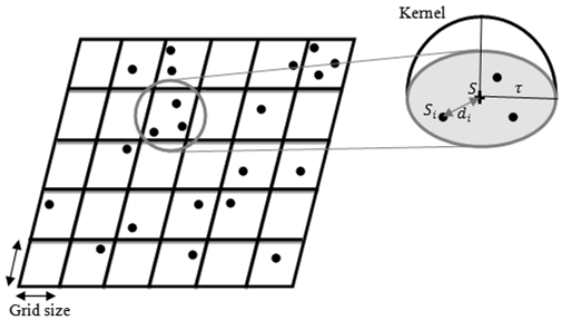


Figure 3: Quadratic kernel estimation

Where $\hat{\lambda}_\tau(s)$ is the intensity of crimes within the bandwidth (τ) as a function of the distance from the center (s). d_i is the distance between the grid centre and the point being investigated.

This intensity is inversely weighted, giving crimes near the centre of the grid cell a greater contribution to the intensity than those further from the centre. As crimes move further from the centre the intensity decreases until finally those on the boundary have an intensity of zero.

To perform this successfully an appropriate bandwidth and grid size must be determined. A bandwidth too large causes excessive smoothing which in turn leads to hotspots not being found. A bandwidth which is too small leads to insufficient smoothing causing a spikey graph, which leads to incorrect identification of hotspots. In this work both the bandwidth and grid cell size are determined using testing where computational time is taken into consideration. The resulting bandwidth for this analysis is taken to be 0.001^o and grid cell size 0.001^o x 0.001^o, measured in the longitude and latitude coordinate system.

Now the objective function is defined with constraints and the hotspot locations have been found the equation can be solved using tabu search.

6 TABU SEARCH

There are many possible solutions to the MCLP. The ideal situation would be to find the optimal solution to position officers in the optimal locations. To find the optimal solution each solution must be investigated, exhaustive search. Doing an exhaustive search would take considerable computational time, making it an impractical approach; hence a method of narrowing the search is required. Tabu search is a method of searching for a solution without investigating every solution. It does not guaranty an optimal solution but has been proven to be an

accurate method of solving similar problems (Gendreau et al., 1997). Hence for this problem tabu search is used to solve the MCLP for police officers.

Tabu search is a form of local search. Local search has the disadvantage of getting stuck at local optima, Tabu search stops the search getting stuck at a local optima as it finds a solution and then moves from this solution to its best neighbour even if this causes the objective value to deteriorate which allows solution to move on from local optima. A neighbour is a solution one move away from the previous solution and the best neighbour gives the maximum value when calculating the objective functions. Revisiting solutions is stopped by using a tabu list, each solution which has been visited is placed on the tabu list and the solutions on this list can't be revisited whilst they remain on the tabu list. They will remain on the list for a selected number of iterations.

Response units are advised to remain in the hotspots they are allocated for a set period of time determined by the police force, typically 15 minutes. If a response unit completes the recommended attendance period of a hotspot this hotspot is marked as visited. Those hotspots recently completed are placed on the tabu list to stop response units revisiting hotspots which have recently been visited and give preference to choosing those hotspots which have not recently been visited. This tabu list is kept through multiple searches. Revisits can be performed only after a certain period of time which is dependent on the strength of the hotspot.

6.1 Tabu Search Process

An initial solution is found randomly and solved using equation (2) and constraints (3)-(8). The neighbouring solutions are then found which are found by moving one officer to a new location per neighbouring solution and they are solved in the same way. The hotspot locations available to position officers will be decided depending on the time of day, day of the week and season. Out of these the best solution is taken and all others are added to the tabu list. This stops the solution cycling back to the same solution and getting stuck at a local optima. This new solution is taken to be the solution and the process is restarted. This process is repeated until one of the stopping criteria is met.

When a stopping criterion is met the best solution is used to position officers. Once the appropriate time to visit a hotspot has passed, e.g. 15 minutes, the problem is solved again to re-determine using the new response unit statuses and locations. A new tabu list is started prohibiting revisiting hotspots which have been visited.

6.2 Stopping Criteria

- The maximum number of iterations has been reached
- The number of iterations since the last improvement has exceeded a set value
- Optimal solution obtained.

7 ROUTING BETWEEN HOTSPOTS

The response units are allocated a hotspot to attend but assumed to take the shortest route to this hotspot. Which hotspot to allocate to each response unit is determined by calculating the routes between the response units and the hotspots which have been chosen by the MCLP. The solution with the lowest overall distance travelled whilst meeting all the constraints is chosen and the response units are allocated accordingly. The routes are calculated using Dijkstra's algorithm.

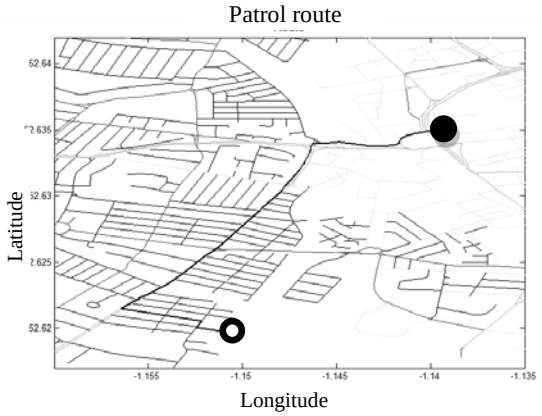


Figure 4: patrol route

Figure 4 represents a typical route between an officer and a hotspot. The circle with no centre represents a police officer. The filled circle represents the centre of the hotspot. The thick black line details the routes to the hotspots.

8 RESULTS

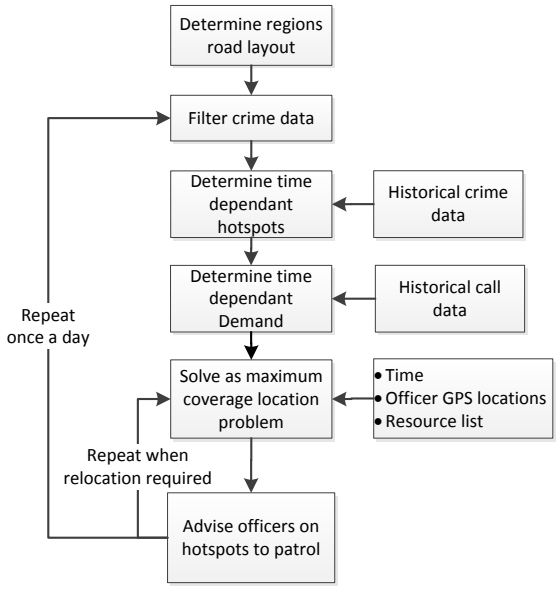


Figure 5: automated positioning process

The resulting process to determine optimal officer locations is detailed in figure 5. The flow chart shows that the road map for the region of concern is developed, the crime data is then filtered and used to determine hotspots, before being solved as a maximum coverage location problem. The results are then conveyed to the response units. The MCLP is solved each time response units require positioning. The hotspots are reevaluated regularly, using the new crime data available, to find new hotspots.

The officer positioning process is tested by simulation. The simulation runs through typical situations which may occur within police response. The officer positioning tool is used when necessary to allocate officers to hotspots. The simulation demonstrates the ability for the tool to determine efficient positioning for the officers.

The first section of the processes is identifying the hotspots. An example of a typical hotspot map for anti-social behaviour, produced by Kernel Density Estimation analysis, is shown in figure 6. The figure shows the hotspots found in Leicester center during the evenings of Friday and Saturday. The red square indicates the area with the highest crime intensity level, followed by orange and yellow. The shades of blue represent a low crime intensity level and no colour indicates that there is no significant case of anti-social behaviour. Out of all the hotspots identified through kernel density estimation the top 3% are used as possible locations to position officers. These hotpots are used to solve for the objective function. Another grid is overlaid onto the map which contains the predicted call demand. This is used to determine what demand is covered when positioning officers. The number of officers is taken to be p which is based on the number of officers on shift and typical availability of these officers. The population in the area determines whether the cell is considered rural or city.

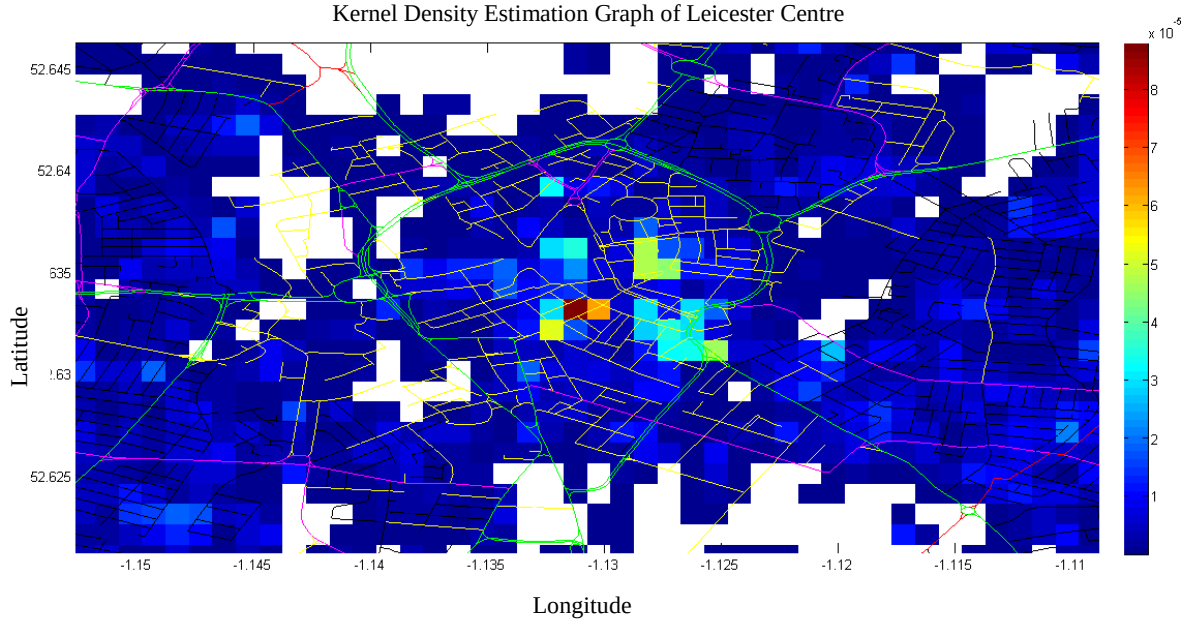


Figure 6: Thematic map of kernel density results.

The performance of the positioning processes is currently measured using historical data to prove its worthiness before testing within police forces. This is done by running the simulation for a period of time in history where crime data has been recorded for. Only crime information recorded before this period starts can be used in the analysis, to simulate the fact that when using the positioning tool in real time the crime data is not available as it hasn't happened. The difference is when using a historical time period the crime data for this period can then be used to determine how well the officers targeted the areas which crimes did occur in within this time period. Hence if the officers had targeted these areas these are the crimes which the officers may have prevented. Equation (10) is used to determine how accurately the positioning tool targeted crime. The equation originates from a study by (Chainey et al., 2008) to determine how efficiently different crime mapping methods predicted where future crime occurred. In this case n represents the number of crimes which occur within the hotspots target by officers, whilst N is the total number of crimes which occur. a is the total area of all the hotspots targeted, whist A is the total area of the region studied.

$$\frac{\frac{n}{N} \times 100}{\frac{a}{A} \times 100} = \frac{Hit\ Rate}{Area\ Percentage} = Targetting\ Accuracy\ Index \quad (10)$$

Using this equation over a one month period allowing for 5% of an officers shift time to be allocated to patrolling resulted in the potential to deter 22% of street crimes. Increasing the time available to patrol would increase the ability to deter crime. Decreasing the time available for officers to patrol would decrease ability to deter crime.

Tabu search offered a search method with lower computational costs than performing an exhaustive search. It did not guarantee the optimal solution though there wasn't a significant difference between the optimal result and the tabu result.

9 CONCLUSION

Dynamic directed patrol routes for response officers are a way of ensuring officers are efficiently placed for incident response whilst also visiting hotspot areas. A program which advises officers on where to patrol is unique and has a place in the current police objective to work more efficiently using predictive policing.

The variation of the double standard model allows both city and rural response time requirements to be considered. It also allows different levels for coverage to be accounted for. Whilst quadratic kernel density estimation effectively predicts crime hotspots as it reduces boundary effects by considering the surrounding areas. This coupled with thematic mapping allows clear graphical representation of crime hotspots. Solving quickly is an important aspect of locating police offices and tabu search gives a shorter computational time than exhaustive search.

The effects of directing patrol routes include a decrease in response times and an increased ability to deter crime. The next stage for this method is to include more methods of hotspot identification, as well as testing in real time within a police force response team. The performance of this method can then be evaluated by testing within the police force. Where the performance of hotspot targeting can be measured by the overall level of crime and the performance of demand coverage can be measured by the change in response times.

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