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Police Implications Associated with Identifying Micro-Hotspots

By Thomas Chengchun Gao; Sungho Ken Park; Jeremy Yablons; and Mark Iris, PhD, Northwestern University, Evanston, Illinois; and Timothy N. Oettmeier, PhD, Executive Assistant Chief, Houston, Texas, Police Department

Policing hotspots has long been considered a valuable tactic to help management direct scarce police resources. The effective implementation of responses to "hotspots" requires police department personnel to analyze mountains of data they routinely gather; however, there is a key obstacle: police departments typically do not have enough skilled personnel or sufficient resources to perform advanced statistical analysis of the gathered data.

The Houston, Texas, Police Department (HPD) has found a creative solution by partnering with Northwestern University (NU). That institution has a highly competitive undergraduate program, Mathematical Methods in the Social Sciences (MMSS), consisting of students possessing strong statistical and analytical skills. An NU faculty member, Dr. Mark Iris, who has a background in policing (retired civilian Executive Director of the Chicago, Illinois, Police Board), realized the potential to solve the issue of insufficient resources—match police agencies with high volumes of data in need of analysis with students having strong quantitative analytical skills who are in need of data for their senior year theses.

Dr. Iris began to serve as a matchmaker in 1997, linking interested students with police agencies. Since then, students have completed more than 30 projects, initially in Chicago, Illinois, and more recently in Los Angeles and Long Beach, California; Philadelphia, Pennsylvania; and Houston, Texas.

Establishing the Protocol

The typical protocol begins with a police department identifying research questions in need of answers that can be developed from data the agency has or can readily generate. Interested MMSS students, in the spring of their junior year, commit to a full academic year—long project, typically working as a team of three students per project, with Dr. Iris as their academic advisor. Each team begins intensive reading on pertinent aspects of policing to become familiar with issues they will need to address.

The entire team flies to the host city and meets with key police managers, technology staff, and crime analysts to begin the process of securing the necessary data from the police agency.¹ The winter is devoted to intensive data analysis, followed by drafting the actual report. In the spring, the team returns to the host agency to present its report to the command staff.²

For the 2011–2012 project, the HPD opted to build upon research done by students in the previous academic year. For the 2010–2011 year, the students had been asked to determine the overlap between on-duty officer time and crime activity. The team examined crimes, calls for service, and officers' self-initiated activity, which were aggregated by police patrol division. "Heat maps" were created to demonstrate if officers were focusing their self-initiated discretionary efforts (when not responding to calls) in those areas where concentrations of crimes and calls for service were greatest.³ In short, were the cops on the dots? The analysis was in general, yes. That analysis was valuable to HPD management, confirming that for most patrol units, crime and discretionary activity were generally well aligned, while highlighting those in need of change.

The Utility of a Micro-Hotspot Grid

The 2011–2012 project, conducted by MMSS students Thomas Chengchun Gao, Sungho Ken Park, and Jeremy Yablons, extended that analysis.⁴ Building on the established concept of hotspots, defined as specific locations for disproportionately large numbers of crimes, Police Chief Charles A. McClelland Jr. tasked the students with examining these trends, not by patrol division, but by identifying definitive micro-hotspots.⁵ The team was also asked to profile these hotspots using a categorization system and, finally, to analyze whether officers' self-initiated activities aligned with the locations and profiles of the micro-hotspots.

The team divided the city of Houston into a grid of small cells, each measuring 700 feet by 700 feet, roughly equivalent to an area of two city blocks by two city blocks. Given Houston's large area (well over 600 square miles), this resulted in a grid of approximately 40,000 cells. The grid was created using a beta version of the Geospatial Modeling Environment developed by Spatial Ecology LLC.

The software package combines components from R, ArcGIS, and Python, and allows sophisticated geospatial analyses to be conducted in an automated fashion and superimposes the geographical distribution of activities (crimes) onto the grid. Thus, the number of activities per cell could be easily counted, rather than relying on a visual measurement and estimate. This analysis also included different charts describing the numbers and types of crimes in each cell and maps showing the geospatial distribution of crimes per cell.

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Establishing the Protocol

The process begins with a police department identifying research questions in need of answers that can be developed into an action plan that the agency has or can readily generate. Interested MMSS students, in the spring of their junior year, commit to a full academic year-long project, typically working as a team of three students per project, with Dr. Iris as their academic advisor. Each team begins intensive reading on pertinent aspects of policing to become familiar with issues they will need to address.

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For the 2011-2012 project, the HPD opted to build upon research done by police agencies in the previous academic year. For the 2010-2011 year, the students had been asked to determine the overlap between in-circuit officer time and crime activity. The team examined crimes, calls for service, and officers' self-initiated activity, which were aggregated by police patrol division. These 'heat maps' were created to demonstrate to officers how they were focusing their self-initiated discretionary efforts (when not responding to calls) in those areas where concentrations of crimes, calls for service, and calls for service were greatest. In short, were the cops on the dots? The answer was an enthusiastic 'yes.' That analysis was validated by HPD management, confirming that for most patrol units, crime and discretionary activity were generally well aligned, while highlighting those in need of change.

The next step was to superimpose this grid on the citywide distribution of crimes and officers' self-initiated (SI) activities. The project started with approximately 3 million crime and 2.3 million SI activity records in Houston spanning seven years, from 2004 to 2011. Data files were cleaned by removing unreasonable values (such as non-existing addresses) and crime types (such as those with too few records for meaningful results).

Also eliminated were artificial hotspots, created, for example, when numerous police crime reports were taken at a police station or hospital emergency room, and the address of the patient was not listed at the crimes' locations.

The research team calculated the number of crimes per cell for 2011, the most recent year for which fall-year data was available. Over 19,000 cells—47.7 percent of the total—had zero reported crimes that year. At the other extreme, one cell had 671 reported crimes. The arbitrary decision to focus on the top 100 cells meant the threshold for inclusion in that list was 116 or more reported crimes occurring in a data. The hotspot concept was again validated: the top 100 cells—one-fourth of one percent of the total cells in Houston—accounted for 10 percent of the total reported crimes.

While the analysis focused on overall crime, the same methodology could be used to identify crime-specific hotspots. For example, the first and third hotspots were shopping malls, and their very high total crime counts overwhelming comprised crimes of the types of theft and larceny. If an agency wanted to do so, it could filter the data to identify the top hotspots for violent crimes and property crimes (murder, rape, burglary, and larceny).

The analysis of crimes by type and time of day for individual areas provided significant insight on crime trends, both for the city in general and each particular zone. In terms of crime types, the analysis confirmed the hotspot concept: crimes are distributed disproportionately both geographically and temporally.

Significantly, this disproportionality has increased from 2004 to 2011. In other words, hot spots and cold spots are getting hotter! This underscores the increasing importance of pimn down hotspots so more effective self-serve tactics can be implemented.

In addition, the analysis showed that different crime types have different disproportionality characteristics. For example, theft within retail stores is concentrated on Fridays, whereas robbery is most commonly during evening and nighttime. Additionally, some crimes are least commonly committed on Sundays, and cross-border analysis observation was that hotspots did not

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exist in a clustered fashion; they are distant from each other. In fact, it is frequently observed that a block has an excessive number of crime records, whereas the surrounding blocks have almost zero crime; this observation emphasizes that identifying micro-hotspots for which the size is block-scale (rather than neighborhood-scale) is crucial in ensuring the effectiveness of implementing policing tactics.

Next, the team examined officers’ SI activity to evaluate how well SI activities align with hotspot locations. Thus, maps in this analysis documented not just micro-hotspots, but also how the distribution of SI activities per cell, as well as the correlation between crime activity count and SI count within a cell. Sorting the records into these cells, the authors noted the type of crime or officer activity, as well as time of day, so they could compare them within each of the 40,000 individual areas.

In addition to analyzing the SI distribution, the team assessed how well SI activities matched with crime levels by calculating correlations of the two across the grid of cells. The correlations are calculated within a range from -1 to 1, where 1 represents the strongest correlation.

Of course, the effectiveness of officers’ SI activities is not solely defined by a simple count of SI activity and crime in a cell. Nonetheless, these calculations, based on a large data set, suggest how well SI and crime activities are located on the dots across years, times of day, and crime types. For instance, the highest correlations occurred during 2008 and 2009, implying that the SI activities were the most in alignment with crime events during those years. The analysis also provided an additional observation: how many SI activities occur in zero-crime areas. About half the city’s cells have no crime, and SI activities were minimal in those areas.

Moreover, the analysis showed that some crime types are better covered by SI activities than others. Drug crimes and simple and aggravated assaults tend to have high correlations with SI activity counts, whereas theft from motor vehicles showed lower correlations. Furthermore, the SI activities seemed to align with crime events better during night and evening than during morning, as evidenced by decreased correlations across almost all types of crimes during that time of day.

The nature of crimes and reporting should be taken into account in interpreting tendencies. For example, the high correlation between SI and drug crimes arises from officers’ direct actions, not by crime victims’ reports to the police.

Overall, from HPD’s management perspective, the correlations were reassuring. Officers, on their own initiative, were clearly investing their discretionary time in fairly close synchronization with levels of reported crimes in individual cells. Intuitively, officers sensed where crime problems were and acted accordingly. This speaks well of the “street smarts” of frontline patrol officers.

Example: Micro-Hotspot 8

This example focuses on the Number 8 micro-hotspot in Houston for 2011, defined as the intersection of Sugar Branch Drive and Forum Park Drive. Satellite photos reveal this is a residential area and shadows suggest the presence of high-rise apartment buildings.

Two key graphs profile this cell. Figure 1 shows 2011 crimes by type of crime; Figure 2 shows crime distribution by time of day. Within each graph, the orange bars show the number for that specific cell; the bars in blue show the averages for the top 100 micro-hotspots.

In Figure 1, by comparing the number of crimes to that of the average for the top 100 micro-hotspots, one observes that assault,
exist in a clustered fashion; they are distant from each other. In fact, it is frequently observed that a block has an excessive number of crime records, whereas the surrounding blocks have almost zero crime; this observation emphasizes that identifying micro-hotspots for which the size is black-scale (rather than neighborhood-scale) is crucial in ensuring the effectiveness of implementing policing tactics.

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Finally, Figure 3 shows types of officer SI activities in this particular area, with each type of activity as a proportion of all SI activities in that cell. SI patrol investments is by far the most common type of activity, accounting for half of all SI activities in that cell for that year. However, the number of incidents was in the actual number of SI events covered in Figure 3 was 217, by contrast, the average for the top 100 cells was 146.26; therefore, the average per cell was only 4.43 activities.

Implications of the Project
The project's methodology and results are pertinent to police personnel in multiple ways, including the following:

1. Many police agencies use crime density mapping to identify hotspots. Typically, this effort provides information on the location of hotspots, the crime type associated with each hotspot, and the time in which the crime incidents are occurring. The difficulty with this approach is the use of algorithms used to create the density map. One cannot always tell where in a particular hotspot a crime(s) is occurring. The "grid system" allows one to pinpoint crime within the actual hotspot clusters (referred to as micro-hotspots).

2. The grid system can be used to guide and direct the allocation of officers to address cell response management. It is not uncommon for officers to observe, over a period of time, the volume and types of calls that emanate from neighborhoods within a community. To the extent that calls and crime are occurring in certain grids, deployment of officers should be able to prevent some of that activity from occurring.

This project delineated ways to create quantitative metrics in measuring macro-level trends of crime disproportionality across locations and the correlation of officers' activities with crime events. These metrics, which can also be measured by time of day, type of crime, and SI activity, can provide insight on how crime patterns are changing and suggest ways to manage police resources. The project's methodology allows an agency to see how disproportionality is changing over time, across crime types, and by time of day.

4. The project demonstrates a way to identify micro-hotspots that are only a...
few square blocks in size. This unit of measurement allows police leaders to utilize their policing resources more effectively by placing officers precisely on the most problematic areas. In short, a police agency can only identify hotspots in its jurisdiction at a micro-level, but can get a nuanced profile of each hotspot to determine what types of crime are most prevalent in the hotspot and when crimes are occurring.

5. Given the extraordinary difficulty of hiring personnel to “expand” one’s operation, one of the few viable alternative options is to repurpose and redistribute “uncommitted time.”

Once time is acquired, it becomes the purview of patrol lieutenants and sergeants to manage how officers use that time. Whether they are directed via their superiors or they self-initially, it is far easier to measure effects within a micro-hotspot using the grid than using amorphous density maps that lack specificity.

6. Much has been said about the value of predicting activities requiring a police response. The grid system adds a degree of precision in determining if crime is moving and in what geographical direction and the degree of intensity occurring within any given cell (how much and what type of crime), both of which might provide insight as to why such activity is occurring.

Currently, the HPD is working on Phase Three of this research initiative. A third wave of students has been tasked with the challenge of creating an instrument to facilitate the “predictive mapping” of criminal activity using the grid system as the tracking device. This research can be extended further, possibly even creating a predictive model of future crime amount and composition. For instance, it was noted that a presence of vandalism signifies imminent coming of other crimes such as burglary. There are mathematical models for predicting burglary counts, on the assumption that a burglary in a neighborhood increases the probability of subsequent burglaries in close proximity.

This has been a wonderful partnership for both organizations, illustrating the value of allowing students with specific skills to assist police as they constantly strive to provide citizens with much-needed services. Students’ efforts have been outstanding and serve as a breath of fresh air in helping police professionals think differently about how to manage their resources. Currently, HPD and MMSS are planning their seventh joint research project.

Granted, there is not a vast pool of students capable of performing this type of work for every police agency in need. However, there is much to be said for working with university professors and students, especially those who bring a unique set of skills and determination to the world of policing.

Notes:

1. Travel costs for these trips have been generously supported by the Weinberg College of Arts and Sciences at Northwestern University, and (for Los Angeles projects) grants from the Los Angeles Police Foundation. No police or other public funds are used in these projects.

2. Students and their advisor normally sign a confidentiality non-disclosure agreement; these reports are proprietary to the individual police departments.

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4. Reorganization of the field shootings

5. Evidence recognition, collection and preservation

6. Trajectory, range-of-fire and entrance/exit determinations, forensic photographic imaging— and more

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