PREDICTIVE ANALYTICS VS. HOTSPOTTING

A STUDY OF CRIME PREVENTION ACCURACY AND EFFICIENCY

EXECUTIVE SUMMARY

For the last 20 years, Hot Spots have become law enforcement's predominant tool for crime analysis. The use of Hot Spots is convenient as they show both the density and intensity of crimes in a given location and are ideal to summarize areas of concern and the types of incidents that occur. However, Hot Spots have severe deficiencies as a crime prediction tool for directed patrols, primarily because they fail to take into account crime trends, crime interactions, and timing.

As law enforcement agencies try to do more with the same or fewer resources, they need a way to better leverage their resources: a Force Multiplier. Predictive Analytics, which provides time–and location–directed predictions, incorporates deeper data, supplies specific prediction outcomes, making it a more accurate and efficient tool for directed police patrols.

To compare the level of accuracy and efficiency of Predictive Analytics vs. traditional Hot Spots, Motorola Solutions conducted a field test using actual crime data from two different cities over 100 days to test two key metrics that should be important to law enforcement: Accuracy and Efficiency.

ACCURACY = Total Crimes Predicted/Total Crimes. This shows how effective the tool is in highlighting where crime will occur.

EFFICIENCY = Total Crimes Predicted/Area of the Predictions. This shows how much area officers are asked to patrol to find the crimes.

The study provided conclusive results that the Predictive Analytics from CommandCentral Predictive is 2.7 to 3.25 times more **accurate** than traditional Hot Spots. In addition, Predictive Analytics is 3.2 to 4 times more **efficient** than Hot Spots, resulting in less area that officers are required to cover in order to achieve better results in preventing crime.

	Hot Spots	Predictive Analytics
Prediction Accuracy Index (PAI)	9.04%	29.64%
Standardized Accuracy Efficiency Index (SAEI)	0.81%	8.78%

AN INTRODUCTION TO MORE ACCURATE AND EFFICIENT POLICING

Law enforcement agencies have now had to deal with declining or flat budgets for the last six years, yet in the face of constraints their mandate is to focus on continuing to lower crime rates. 49% of agencies recently polled expected their budget to remain flat in 2014[1], with another 23% expecting a decrease in funding. The continuing challenge for all agencies is how to do more with less.

There is a new wave of technology called Predictive Analytics that has swept many commercial industries and promises to do the same for public safety. Predictive Analytics uses advanced mathematical modeling to help predict future behavior and is successfully used by many organizations to be more effective. Today's law enforcement agencies are eager to understand how Predictive Analytics can be used to successfully prevent and reduce crime, and whether "Big Data" analysis can help their agencies prevent and reduce crime within the constraints of existing resources.

However, Predictive Analytics is more than just another way of analyzing data. It is a method to make an agency more accurate and efficient in how and where it deploys its greatest resource: patrol officers. It promises to provide a significant step forward with analytics that bridge the gap between the data and officers in the street, and makes them more efficient by placing them in specific areas where crime is likely to occur. This whitepaper is designed to help readers understand through actual field data, how much more accurate and efficient agencies can be with Predictive Analytics

The early introduction of crime mapping was mainly focused on looking at correlation of crimes and demographic or geographic factors. Early maps in the 1800s looked at various crime rates by incident type in geographic segments, or associated crimes with primarily male demographics or other data. In this capacity, crime maps were designed more to explain and observe crime than as a tool to enable officers to fight it directly.

Given the long history of crime mapping, it is surprising that the development of spatial and analytical tools didn't occur until very recently. The direct use of real crime analysis started with the introduction of Spatial and Temporal Analysis of Crime Ellipses or STAC in 1980s and 1990s by Samuel Bates. Drawing on forty years of research on a concept of Nearest Neighbor Index or Nearest Neighbor Analysis, whose roots are in botany, Bates conceptualized the use of drawing ellipses around crimes, while connecting the closest ellipses together, and the Hot Spot was born.

The Hot Spots that Bates created looked at both spatial (location) and temporal (time) factors, and showed them through and indication of the density (the number) and the intensity (the frequency) of crimes. It was recognized that this was a revolution in crime analysis. At the time, David Coldren, Executive Director of the Bureau of Justice Statistics (BJS), which funded Bates', research stated that,

> **"One of the more promising techniques is what we've been calling our hot spot procedure. This is a procedure designed to look at all the crimes within a given area (such as a town) and search for the place of highest crime density, or where most of the crimes occurred. This is the so-called hot spot."**[2]

Most revolutionary about the concept of Hot Spots was the fact that it finally provided agencies with a sense of priority and focus. The purpose of Hot Spots was to show where and how much crime was occurring in a given geographic area, so that more resources and effort could be placed on preventing crime in those areas that needed the most intervention.

In other words, Hot Spots started to focus law enforcement tactics on two important elements of their planning: How to be more efficient in focusing on the right areas, and how to be more accurate in deploying their resources at the right place.

While Hot Spots have been and will continue to be a valuable tool for law enforcement agencies, it is increasingly recognized that Hot Spots are limited in their ability to provide more than a general overview of the types and intensity of crimes that are happening in a given area. Typically, they are useful for prioritizing areas, CompStat discussions, and monitoring general activity.

However, as law enforcement agencies seek for better utilization of their resources in the face of budget constraints, they are looking for techniques that continue to improve:

ACCURACY	EFFICIENCY
Highlighting the correct areas where crime will occur	Focusing on the smallest area possible to prevent the majority of potential crimes.

These two concepts work inversely to each other. For example, an agency could be very accurate in being in the same location as a crime, if they placed an officer on every block in a given area, thus preventing or catching 100% of the crimes that occurred. However, they would be very inefficient because they would have had to place officers on every block 24 hours per day. So, accuracy and efficiency always need to be balanced for the optimal results.

Hot Spots have severe limitations in providing correct information that is both accurate and efficient. Specifically, Hot Spots fail to take into account longer, historical trends, probability analysis, and rigorous quantification of the interactions between crimes that are required to make more than generalizations about the types and density of crimes.

Predictive Analytics, by contrast, provides a deeper perspective on crime analysis that optimizes both efficiency and accuracy. Rather than providing sweeping summaries of past crimes, Predictive Analytics provides highly targeted forecasts of future crime based on four key elements:

1. **LOCATION**
2. **TIME OF CRIME**
3. **HISTORICAL CRIME PATTERNS**
4. **INTERACTION OF CRIMES**

The Predictive Analytics technology in Motorola Solutions' CommandCentral Predictive uses these different factors in its dynamic probability models to determine where and when crime will likely occur, providing detailed and specific information that makes patrol officers more accurate and more efficient.

The best way to demonstrate this is by creating a side-by-side comparison of Hot Spots and Predictive Analytics target prediction boxes to contrast the differences in accuracy and efficiency. In other words, this test would ask the question, Which method can more frequently pinpoint the right location of crime incidents (accuracy) by sending officers to the fewest locations (efficiency)?

For this comparison, Motorola Solutions ran a study that tested the crime predictions from its CommandCentral Predictive product with traditional Hot Spots in two different cities for a period ranging from 90 to 100 days. For each day, it produced crime predictions for the agency by calculating the highest likelihood of crime, which was then laid over the city map according to the prediction's latitude and longitude coordinates. In addition, it calculated crime Hot Spots using a well-known Hot Spotting technique called Prospective Hotspotting. This methodology consists of laying a grid over the heatmap and choosing boxes based on the density of historic crime that falls within them. It then calculated the accuracy and efficiency of both the Predictive Analytics crime predictions and the crime Hot Spots for each day over the duration of the test using the actual crimes that occurred on the following day.

SETUP

The predictions in this comparative evaluation were provided for an area of 500x500 feet. The total number of prediction boxes generated by both techniques was fixed as well, thereby keeping constant the total area covered by the boxes in each case. To have a statistically significant comparison, the experiment was run for 90-100 days. Each of the two techniques produced look-ahead predictions for one day at a time. The same historic data of 1000 incidents for any given day was used by both the techniques at any given day in the experiment. This setup was replicated on crime data sets from two different agencies based in the US. Both agencies are urban areas: City 1 has a population of approximately 506,000 and City 2 a population of approximately 160,000. We present the results obtained in conjunction with the evaluation metrics that we introduce below to measure the accuracy and efficiency of these predictions.

EVALUATION METRICS

The test used two standard metrics to validate accuracy and efficiency of the methods based on the numbers of 'True Positives or Correct Predictions', 'False Positives or False Alarms' and 'False Negatives or Missed Predictions' generated by the prediction methods. These concepts are widely used in the area of Statistical Machine Learning to evaluate all kinds of Prediction and Object Recognition/Classification algorithms and thoroughly in classical Statistics to quantify the power and significance of the results of testing any statistical hypothesis (Hypothesis Testing) and of late, in this Internet age in the applied field of Information Retrieval to measure the performance of an Internet Search Engine or to measure the relevancy of search results retrieved from a database. Within the setting of crime predictions using prediction boxes of fixed areas, these concepts are interpreted and laid down below for quick reference:

- **TRUE POSITIVES** Number of Successful Predictions of Crime
- **FALSE POSITIVES** Number of False Alarms or Incorrect Predictions
- **FALSE NEGATIVES** Number of Crimes not predicted

ACCURACY

Incorporating these within our setting of predicting crime, the "Accuracy" of the system can be truly measured and compared across experiments by the simple ratio:

$$\text{ACCURACY} = \frac{\text{True Positives}}{\text{True Positives + False Negatives}} = \frac{\text{Number of Hits}}{\text{Total Crimes Occured}}$$

This index is bounded and produces values between 0 and 1.

OBSERVED EFFICIENCY

In the same fashion, the efficiency of the crime prediction system, in terms of the area covered by the prediction boxes can be quantified by the simple ratio:

$$\text{OBSERVED EFFICIENCY} = \frac{\text{True Positives}}{\text{True Positives + False Negatives}} = \frac{\text{Number of Hits}}{\text{Total Prediction Boxes}}$$

ACHIEVABLE EFFICIENCY

For a fixed number of prediction boxes, and of a fixed area of a box, the maximum achievable Observed Efficiency while comparing two or more techniques can be quantified by a ratio:

$$\text{ACHIEVABLE EFFICIENCY} = \frac{\text{Total Crimes Occured}}{\text{Total Prediction Boxes}}$$

STANDARDIZED ACCURACY EFFICIENCY INDEX (SAEI)

A standardized, combined index of efficiency and accuracy for fixed boxes and areas can finally be obtained by combining the above two measures of efficiency:

$$\text{SAEI} = \frac{\text{(Achievable Efficiency – (Observed Efficiency*Accuracy))}}{\text{Achievable Efficiency}}$$

The maximum achievable product of Observed Efficiency and Accuracy is given by Achievable Efficiency, as the maximum Achievable Accuracy is 1. The SAEI that we introduce compares the product of Observed Efficiency and Accuracy with this maximum achievable product and is a combined predictive index. The higher the SAEI, the better is the accuracy and efficiency of the predictions.

OPTIMIZING PREDICTION BOXES AND AREA

Every agency is unique in terms of its area, shape, demographics, crime statistics and density of crime. Accuracy and efficiency are inverse quantities and empirical evidence supports this fact: predicting that crime will occur in an area that covers the entire agency jurisdiction will be 100% accurate, but that is not very efficient.

Knowing this, optimizing the number of prediction boxes and/or the size of the prediction boxes is critical and can be best tuned automatically from historic data to get the best trade-off of accuracy and efficiency. CommandCentral Predictive is designed to do just that: to give you the best combination of both worlds by automatically learning the right prediction parameters parameters for your agency along with a host of other mathematical, model-parameters and corresponding statistical metrics which are optimized using historical data to produce accurate and efficient predictions.

EVALUATION AND RESULTS

The comparative results for City One from our study are shown below in Table 1. On each day of the experiment, both techniques were individually used to predict the areas where crimes could occur the following day. During the study, CommandCentral Predictive successfully predicted 29.64% of crimes over a period of 98 days as against hotspotting, which predicted only 9.04% of the actual crimes. A combined index of accuracy and efficiency, SAEI of 8.78 % was observed in the results of CommandCentral Predictive as against only 0.81% in hotspotting.

TABLE 1 BURGLARY RESULTS – CITY ONE
Population approx. 506,000

	Hotspotting	CommandCentral Predictive
Hits	36	118
Total Crimes	398	398
Accuracy	9.04%	29.64%
Total Boxes	2940	2940
Observed Efficiency	1.22%	4.01%
Achievable Efficiency	13.53%	13.53%
Stardardized Accuracy Efficiency Index (SAEI)	0.81	8.78%

The results from City Two show similar results for accuracy and efficiency of CommandCentral Predictive vs. Hotspotting, as shown in Table 2. In this case, CommandCentral Predictive successfully predicted 29.16% of the crimes (56 out of 192 crimes), vs. hotspotting, which successfully predicted only 9.89%. In addition, CommandCentral Predictive was also about three times more efficient, resulting in a relative efficiency rating of 8.47% vs. only 0.97% for Hotspotting.

TABLE 2 BURGLARY RESULTS – CITY TWO
Population approx. 160,000

	Hotspotting	CommandCentral Predictive
Hits	19	56
Total Crimes	192	192
Accuracy	9.89%	29.16%
Total Boxes	3000	3000
Observed Efficiency	0.63%	1.86%
Achievable Efficiency	6.4%	6.4%
Stardardized Accuracy Efficiency Index (SAEI)	0.97%	8.47%

The comparative results show that when considering both accuracy and efficiency across the two techniques, Predictive Analytics has a clear advantage in providing accurate predictions of where crime will occur, while maintaining a high level of efficiency. In the case of the two cities observed, the uplift of both indices was more than 3 times that of Hot Spots.

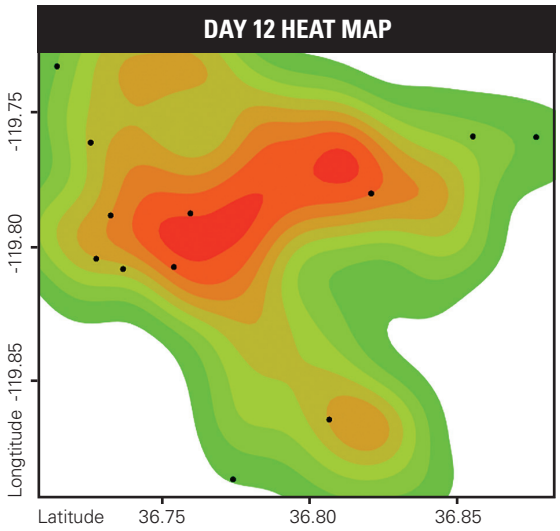
TACTICAL APPLICATION – A DAY AT A TIME

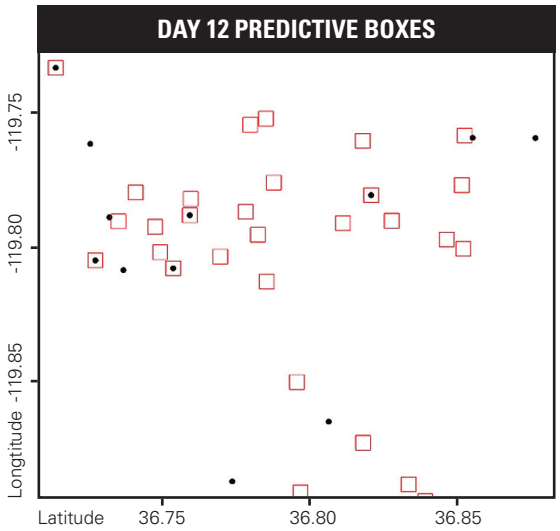
While our study covered a 100-day period, it's also important to see how the two separate methodologies affect the daily tactical application of assigning patrol. The images below represent the latitude and longitude coordinates of City One – an area of 112 square miles – to provide a comparison of output using both Predictive Analytics and Hot Spots, along with the following day's crimes. The Hot Spots and prediction boxes were generated for the same day.

The image on the left shows a multi-zone heat map, or Hot Spot. The dark red represents a higher historical density of crime incidents while the range from orange to green highlights an ever-decreasing count of crime incidents. If an agency's command staff were to assign patrol on this day, the typical response would be to concentrate a higher number of officers in the dark red areas. However, out of the 12 incidents that occurred on this day, just three occurred within relative proximity of the historical trend. 75% occurred in the "cooler" regions.

Likewise, the image on the right includes a series of prediction boxes, taken from CommandCentral Predictive, over a one day period. These boxes represent the areas where there is highest likelihood of an incident occurring on this day. Each box is 500 x 500 feet. The typical directive would be for an officer to spend more time patrolling in and around these areas on this particular day as part of their regular patrols. Overlaying the next day's actual crime data shows that seven of prediction areas had actual crimes occur in them, in this case representing 58% of the crimes covered in a small geographical area. This contrasts to the much larger patrol area needed when using Hot Spots, which only covered 25% of the crimes.

This visual demonstration provided is exemplary, but it serves as a realistic example that the use of predictive analytics can provide agencies with targeted crime predictions on a daily basis that are more likely to focus them on areas where crimes will occur, and provide them with less area to focus on.





CONCLUSION

Predictive Analytics allows agencies to become more accurate and efficient in their policing efforts by highlighting key areas and time-periods to do more with less. As demonstrated in this paper using actual field data, CommandCentral Predictive can make agencies both more accurate in finding crime, and more efficient in the areas they need to focus on.

While Hot Spots will maintain a role as an important tool for general crime analysis, in today's climate of needing to make a greater impact on the safety of our communities without additional resources, Predictive Analytics promises to provide new levels of accuracy and efficiency in crime prevention and improving public safety.

Motorola Solutions connects people through technology. Public safety and commercial customers around the world turn to Motorola Solutions innovations when they want highly connected teams that have the information they need throughout their workdays and in the moments that matter most to them.

Our customers rely on us for the expertise, services and solutions we provide, trusting our years of invention and innovation experience. By partnering with customers and observing how our products can help in their specific industries, we are able to enhance our customers' experience every day.

SOURCES

1. Public Engines Survey of North American Law Enforcement Agencies, June 2013
2. Coldren, J. David. Application of Spatial and Temporal Analysis to Law Enforcement. Presentation to the Illinois Criminal Justice Information Authority, June 3, 1986.

For more information CommandCentral Predictive, visit
motorolasolutions.com/commandcentralpredictive.

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