Narrowing the Search: Utilizing a Probability Grid in Tactical Analysis

Bryan Hill[1]
Crime Analyst
Glendale Police Department
6835 N 57th Drive
Glendale, AZ 85301
(623) 930-3073
bhill@ci.glendale.az.us

Narrowing the Search: Utilizing a Probability Grid in Tactical Analysis

Bryan Hill[1]

Abstract

This paper addresses the use of the "probability grid method" (PGM) as it pertains to tactical crime analysis in the ArcView Geographic Information Systems (GIS) environment. A specific robbery series from the metro Phoenix, Arizona area is analyzed by applying the PGM process.

The main point in this paper will be that any current statistical method of predicting the next hit location in a crime series are operationally ineffectual when the suspect covers a large geographic area. When the analyst combines several statistical methods and intuitive, logical thought processes into a combined "grid" score, the analysis product can be made more operationally effective. This new grid surface allows the analyst to make a better prediction of the next hit in a crime series and is useful in isolating specific target locations for law enforcement deployment efforts. This easy to apply "PGM method" allows the analyst to use sound statistical methods, as well as their experience and knowledge of a crime series to narrow the focus and potential hit area.

In addition, when the crime series has sufficient suspect information, journey to crime analysis using the CrimeStat software can be used to provide investigators with a list of probable offenders from law enforcement records available to the analyst.

Key Words: geographic, apprehend, criminals, serial, spatial, analysis, probability grid

Word Count: 7,497 words, 21 Pages

Introduction

Crime mapping has led to new and innovative ways to analyze crime and criminals in the past several years. The practicing crime analyst is often faced with problems in tactical analysis that require creative methods to overcome. These problems can be placed into the category of "too much land and not enough resources." When doing tactical robbery analysis in Glendale and Phoenix, Arizona, the results from common rectangular (Gottlieb[2]) or elliptical predictions (Levine[6]) often result in a 25-50 square mile area where the suspect may commit a new crime in a series. Undercover and detective units have a difficult time using this information in the practical environment. In order to narrow the focus for the investigators, a crime analyst must apply and use several types of data and methods to find the one that is the most operationally effective. Many of these methods are statistical, however the analyst's experience, knowledge of the crime series being analyzed, and his or her "gut feelings" are sometimes called upon.

A "probability grid" is a natural evolution to this problem and allows sound statistical methods to be combined with investigator and analyst experience of crime series events. This method may seem to be difficult to use at first, but is fairly easy to implement with the tools analysts have available to them. A probability grid leads to more practical analysis for predicting the potential location for subsequent crimes in an identified series. When combined with journey to crime analysis, it also enables "person" information, such as probation, citation, and field interrogation data to be used by the investigator to identify potential suspects in unsolved crimes. The goals established for all tactical analysis efforts still apply to a probability grid analysis:

1) Predict the location, date, and time of the next crime in the series that is *operationally useful*, *timely*, and *practical* to the units involved.
2) Optimize the placement of undercover or "stake out" units to catch the criminal "in the act."
3) Identify potential suspects from person data sources collected by the police department and provide this data to the investigators.
4) Assist in the identification of the geographic area where the suspect or suspects may reside using CrimeStat's Journey to Crime Analysis (*Ned Levine and Associates*[6]) or other methods such as Geographic Profiling[10] to *limit the number* of potential investigative leads.

In order to use the "probability grid method" (PGM), the analyst needs to combine current statistical probability processes and his or her own experience to determine the best possible location for the next crime in a series. This is accomplished by creating a new "grid" layer where each "cell" is the same size. The analyst will then score each grid cell based on its geographic or spatial relationship to other layers that have been selected based on whether they matched certain criteria related to the crime series.

This process has proved successful in predicting the next hit location in approximately 14 crime series events in Phoenix and Glendale and led to the identification and arrest of a robbery and murder suspect.

Background

In the late part of 1997, the Crime Analysis Unit for the Phoenix Police Department began to fully apply tactical crime analysis techniques to certain robbery series analysis efforts. The General Investigations Bureau, Robbery Detail, initiated these tactical efforts by bringing several on-going robbery series to the attention of the Crime Analysis Unit staff. While initial efforts proved enlightening and established the use of GIS to support investigative processes, predicting the next hit location was at most interesting, but not very practical. The crime analysts assigned to the unit were novices at tactical analysis although the author had over 18 years of sworn police work to his credit at that time. The unit's available tools consisted of ESRI's[12] ArcView GIS product, The Omega Group's Crime View[13] extension, and the basics of crime analysis processes obtained from Steven Gottlieb's[2] crime analysis book, "Crime Analysis: from first report to final arrest."

Gottlieb[2] Rectangles:

The first map that was created by unit staff resembled figure 1. The only method known to the analysts at this time, was the basic method, taught by Steven Gottlieb[2]. This process involves the creation of a probability "rectangle." Figure 1 shows a current analysis effort for the "Video" or "22 Rifle Bandit." A huge prediction or probability area problem exists when the offender covers a large geographic area to commit his offenses. This makes perfect sense, in that, what you are actually predicting is the area where 68% or 95% of the total crimes have been committed up to this point in your analysis. The idea is that if 68% or 95% of the crimes have been committed in this geographic area, then the same probability exists that a new crime in the series will also be within these areas. As you can see from figure 1, the area for the 68th percentile (red square, 10.8 square miles) and 95th percentile (yellow square with red outline, 43.4 square miles) are very large. This was largely caused by the fact that this robbery series covered most of Phoenix. The first sets of crime series analyzed by the Crime Analysis Unit also included adjoining cities, further increasing the geographic area. The Phoenix Police Crime Analysis Unit staff found that Gottlieb's process is very effective when the analysis area is small. They also found that this probability method was not as operationally effective when the crime series covers a large geographic area. The mapping products provided to the investigators also proved to be lacking in operational usefulness.

A short discussion on how to create Gottlieb's[2] rectangles follows.

Creating Gottlieb[2] Rectangles:

The basic process requires you to know the X and Y Coordinates of the crimes in your series. Once you have obtained them through a hand-drawn method, or using a computer mapping application to "geocode" the events, you must then find the mean, and standard deviation of the X and Y coordinate sets. Once you have the mean and standard deviation, you should set up a table similar to table 1 that will give you the corners for the 68th (1 standard deviation) and 95th (2 standard deviations) percentile areas.

TYPE	X_COORD	Y_COORD
MEAN	450665.82076	897522.94174
MEAN+1STDEV	476876.09204	920662.48708
MEAN+2STDEV	503086.36333	943802.03241
MEAN-1STDEV	424455.54948	874383.39641
MEAN-2STDEV	398245.27819	851243.85107
*ULC-68%	424455.54948	920662.48708
LRC-68%	476876.09204	874383.39641
ULC-95%	398245.27819	943802.03241
LRC-95%	503086.36333	851243.85107

Table 1
X and Y Coordinate Table for Creating Probability Rectangles (*ULC=Upper Left Corner, etc.)

(The X and Y coordinates for this table were obtained from an actual robbery series in Maricopa County and are based on the NAD 27, Arizona Central, Feet, projection.)

Once you have obtained these numbers, you then place points on your map and connect the corner points to make the rectangles. This can be easily done in a computer mapping program. *(The examples in this paper* *utilize the author's Crime Analysis Tools Vers. 2.0 extension to ArcView – see Appendix A)*

Probability rectangles have proven to be useful in many cases since a chance that the next crime will occur in these 68th or 95th percentile areas is a reasonable assumption. In initial analysis attempts (Blue Bandits[3], Super Sonic Bandit[4], and Cuchillo Bandits[5]), the same type of large geographic region was encountered. When the types of stores were added into the GIS project, hundreds of potential targets were identified and proved to be of limited usefulness to investigators wanting to know where to deploy to "catch" the offender. In fact, in two of these robbery series, over 300 stores or targets were identified. These 300 or more stores were in the 95th percentile area derived from the probability rectangle method.

In the actual case study of the Video Bandit, this method identified 21 video stores as potential targets inside the 95% prediction rectangle. Assigning officers to watch all 21 potential targets during the date and time that the offender is most likely to strike again is not reasonable. Limited resources within police departments would not allow each and every one of the potential targets to be "watched," waiting for the offender to saunter in and rob one of them. The practicality of the information and maps becomes less useful to the investigating units and proved to be discarded in most cases. The decision on which target to sit on had more to do with the robbery detective's experience and "hunches" than the maps or analysis products themselves.

The decision-making assistance this method offers does have some benefit, however through capitalizing on the investigator's experience, and addition of other methods and data, the crime analyst can improve the prediction and reduce the number of targets. Typical crime analysis courses, dealing with tactical crime analysis, suggest that finding the "one magical method" that is both fast, and efficient, at determining the next likely target, is the objective. This paper hopes to show that there may not be one method that far excels at predicting the next hit location when the offender's pattern covers a large geographic region. A combination of several simple geographic criteria, that include standard spatial statistics and general geographic relationships, will yield a more operationally useful product.

The assumption taken in the PGM process was that no "one" method was any better than another and combining methods would prove to be a lot more successful. In general terms, all statistical methods appear to be as effective as another in predicting or forecasting the next hit. The belief that an investigator's or trained analyst's experience is an aide to doing quality analysis, is widely accepted in many departments. All crime analysts can doubtless say that an investigator has once told them that they could do better using their "gut feelings" than the analyst could do with a calculator, pen and paper. The analyst needs to understand the thought processes "investigative experience" brings to a predictive attempt and try to quantify it or repeat the success from one crime series to another. What are the similarities and patterns the investigator or crime analyst can see in a crime series? What is known by the investigator or crime series about these suspects that can aide the predictive aspect of the analysis?

Completely quantifying investigative experience and being able to repeat it, may not be a realistic endeavor, however, statistical analysis and methods can be followed to validate that experience and make the process more reliable in all analysis efforts. The more *easy to understand* and *consistent* the analysis product is, the more useful the product is to the operational mission of a police department. The crime analyst's work product must be evaluated after each analysis and modified as needed so that it can be constantly improved. The only way to improve something is to test its effectiveness and the analyst's ability to repeat results in other crime series cases.

In addition, if an analyst does not develop good communication with the investigators involved in these cases, the product of his or her analysis may not get fully utilized and validated within his or her own agency.

In addition to Gottlieb's[2] process of creating probability rectangles, the standard deviational ellipse approach is also widely accepted as a valid and useful technique.

Standard Deviational Ellipses:

Standard deviational (SD) ellipses can be created using several different applications. The same basic math is used to create ellipses as in the probability rectangle process. The mean and standard deviation are used in this method as well. The areas identified by both methods are very similar in size.

For the purposes of this paper, the NIJ funded application, Crime Stat[6], was used to create the ellipses. Other applications such as Crime View's[13] process and of course the Crime Analysis Extension[12] can be used to create SD ellipses. Any of these programs are useful, valuable, and fairly easy to use, once you have practiced with them. For this paper, the process in CrimeStat (figure 3) is the only one that will be discussed (*See Appendix A for step by step directions).*

When created and applied in the Video Bandit series, the SDE ellipses actually increase the size of the area where the next crime could occur. The actual square mileage of the SD ellipses is 75.5 square miles (95%) and 18.9 square miles (68%). In the Video Bandit example, there are 27 potential video store targets within the 95% SD ellipse. This method adds another 6 stores to the 21 identified with the rectangle method. Instead of decreasing the probability area, we have increased it using the SD method.

The SD ellipse and probability rectangle methods are the most prevalently used in the crime analysis community and have been reportedly successful in predicting an offender's next hit. For robbery series covering large geographic areas, neither method appears to provide a better operational predictive tool. Both of these methods did predict the next hit location in the Video Bandit series because the final robbery did in fact occur in the 95th percentile areas, however that was a very large area, and was not useful to investigators in actual practice. It was obvious that a new method had to be developed that created a much smaller geographic focus area for investigative unit deployment. This method had to reduce the probability area, and had to do a better job of isolating the specific target stores that were the most likely to be hit by the suspect.

Developing the Probability Grid

Many analysts have utilized a "grid surface" to predict the location of the next crime in a series. Dan Helms[9] and several others may have been the first to explore this idea as it relates to tactical crime analysis. This approach is not new to the crime analysis field and this paper does not suggest that PGM is innovative or vastly superior to any other method currently being employed. Combining several methods to achieve a better predictive model, has been discussed widely in the field in the past, and the PGM process is just one method that has proven to be easy to implement in two police departments in Arizona. The goal of this paper is to describe a procedure that appears to be reliable in at least one agency. In addition, encourage others to try the PGM process and report on their success and failures. Another goal is to encourage open discussion on making a more easy to use, reliable, and useful operational product for police departments doing this type of analysis.

The PGM process had to be relatively fast to create and easy to understand by any analyst who may choose to try it. Considering that the Phoenix crime analysts were mostly novices at tactical analysis, a great deal of trial an error was involved in establishing the current process. Much of the development of the PGM process relied on what was currently available to the Phoenix Crime Analysis Unit personnel.

The Police Grid Layer Is Used For Something New

Many agencies use various geographical boundaries to describe areas within their city to deploy resources and assign patrols. Phoenix had developed a grid layer that followed the street centerline to use in determining the correct precinct or beat for dispatching calls for service. This police grid layer consists of fairly equally sized quarter square mile polygons and has stayed relatively stable for the last 20 years. This grid layer proved to be a natural container for the initial attempts at "scoring" grids based on multiple, decision-making criteria.

The next genesis in the “Probability Grid” then began to develop with the efforts of Paul Catalano[7]and Brennan Long[8]. A collaborative effort between Catalano[7], Long[8] and the author, resulted in a paper being published in the Security Journal[10] concerning predictive efforts in several robbery series in Phoenix. The actual details of that paper will not be covered in-depth in this report, however why the probability grid was developed is based on the logic and research described in that paper by Catalano[7]. Paul Catalano[7] was the main author of that paper and developed most of the methodology relating to a probability grid. The Phoenix Crime Analysis Unit staff was able to use that research and his basic methods to create a product that allowed them to use statistical analysis (ellipses etc.) and other decisions based on experience, and spatial relationships to make a more operationally useful prediction.

Three key concepts were developed in the Catalano’s[7] paper that should be discussed. The first is that any tactical analysis prediction for a crime series where the suspect covers a large geographic area may be too large for operational effectiveness within a police department. Second, several factors and easily obtainable data can be combined to make a better decision based on crime theory, spatial or basic geographic relationships, and individual series details. Third, the result of the combined data and methods could provide a more useful analysis than one method alone.

After several robbery series were analyzed, the following items were established as useful for both creating the probability grid and applying it:

1. What are the 68% and 95% areas identified with Gottlieb’s rectangles?
2. What are the 68% and 95% areas identified with the SD ellipses?
3. What types of targets are being chosen (victimization: convenience stores, supermarkets, etc)?
4. What is the average distance between hits?
5. Are any targets or areas victimized more than once? And is this an important pattern?
6. Are there any targets of a similar type anywhere else and where are they?
7. Are there census items that are peculiar to the target selection (expensive neighborhood, predominantly Asian/Hispanic, medium density commercial vs. single family residential, a lot of vacant homes or average home valuation consistent among crime locations, etc.)?

8. Does there seem to be a travel pattern from hit to hit and can the direction of the next hit be rationally determined from observing the travel pattern for the crimes in order of occurrence (crime path analysis)?
9. What is the area covered inside a minimum convex Hull polygon of the crime series points?
10. Can potential “escape routes” or “ease of escape” factors, available to the suspect, be determined (length of main street/freeway network, etc.)?
11. Are there any other factors that help narrow the focus provided by the investigator or crime analyst’s experience for this crime series (suspect description, MO, witness tips, etc.)?
12. How are all of these items related spatially?

In order to satisfy these questions for every crime series being analyzed, several sets of data need to be obtained by the crime analyst. These items can be changed or modified as needed to fit the agency using this method.

- A good street centerline to geocode the crime incidents
- A program to create the probability rectangles and SD ellipses
- A program to create a complex Hull polygon of the crime points
- A source for business point data to find potential targets
- The ability to calculate the distance between hits, and create a buffer around the last hit in a series
- The police reports for every crime in the series with all investigative supplements and materials
- Related spatial data for the area such as land use, census, and other community-based data sets

Most of these sets of data and programs can be obtained through the police agency, a city planning department, or other source. Once these items are collected, then the analyst applies the beginning stages of creating a probability grid (as shown in figure 2). The steps to creating a probability grid are listed as follows:

1. Gecode the crime incidents using GIS software *(ArcView 3.2a was used for this paper)*
2. Using the points and their relative X and Y coordinates, calculate the 68% and 95% probability rectangles
3. Create the SD ellipses
4. Calculate the distance between each crime in the series, and establish the mean, and standard deviation of this distance
5. Create three buffers in the GIS software around the last hit in the series based on either the average distance traveled between hits, or if widely varied, use the standard deviation. *(This may involve looking at the data with respect to determining if any patterns exist in the suspect(s) actions. For example, an offender may switch from traveling 2 miles to 15 miles from the last hit over the course of the series, etc.)*
6. Geocode the locations of any businesses that may be appropriate for analysis based upon the victimization data.
7. Create a convex Hull polygon of the crime points
8. Add in census and land use data and determine characteristics of current target areas selected by the suspect to see if there are any common factors among the targeted locations. *(This is more useful when dealing with an offender who is hitting targets at random with no particular type being*

evident. It can include such things as average main street length in a grid, distance from a freeway, home valuation, ethnic breakdown for an area, tips from witnesses and informants, where vehicles used in the robberies were stolen from in relation to the robberies, etc.)

9. Create a grid polygon of equally sized "cells" and create several fields to calculate the various scores from the other spatial data sets that have been created.

Setting the Grid Cell Size:

Setting the grid cell size for PGM is a judgement call and may be different for each agency that may employ it. The major concern is that the final grid surface clearly identifies areas where the suspect is most likely to commit a new crime in the series. Some consideration should be given to visual appeal for the map since investigators are not normally graphic artists or crime mapping experts and want to be entertained as much as provided useful analysis products. As your series boundary decreases you may want to consider decreasing the size of each grid in your theme, however, it is not recommended to use a grid larger than .25 square miles nor smaller than 0.01 square miles. When considering smaller polygons, remember that a 0.01 square mile grid is approximately 528 feet by 528 feet. Most geocoded data has some geographic error in it, and thus the smaller you get may improve the final “look” of your map, however the accuracy of your analysis may not improve due to these errors. It also takes GIS software like ArcView, much longer to create a probability grid layer with the cell size set to .01 than it does at a setting of .25 square miles.

In the Video Bandits example in this paper, a .25 square mile cell size was used and the result was satisfactory. A grid cell size of .10 square miles would have created more grids, and would have been more useful if there were larger numbers of video store targets in a closer proximity to each other. It is cautioned to be reasonable in selecting the cell size and not try to find the one building the suspect may try to hit next (although the investigators would probably love you for that).

Using the census blocks or tracts may be useful, since each cell will no longer be exactly the same size the results may be skewed in areas where the tract sizes vary greatly.

Using a new polygon boundary theme of equal size and shaped cells may minimize errors in data sets you use and will provide a more reliable and unbiased result. Some experimentation may be necessary to identify the most suitable cell size. It is important to maintain consistency in the methodology so that so that your successes and failures can be evaluated honestly, but the methodology should be flexible enough to allow important aspects of individual series to be taken into account. In some cases, the consistency in a suspect’s pattern suggests that a particular factor should be scored more heavily. An example of this might be a travel path analysis where the offender is traveling to crime locations with a very consistent 10 mile distance from hit to hit. This could be weighted by a factor of 2 or 3, because in this series, the 10 mile distance is very consistent and identifies this offender’s pattern.

When all of these elements are available in a robbery analysis, the probability grid can be created and used to reduce the number of potential targets that are “most likely” to be the victim of a new crime in the series. Although there is still no magic bullet for these types of predictions, the PGM process provides an operationally useful product with a satisfactory success rate.

A Field-Tested Example

In the Video Bandit series, there were a total of 11 robberies and one homicide before the suspect was apprehended. In order to demonstrate the capabilities of the probability grid method, the first ten robberies are used to try and predict the location for the 11^{th} hit. This technique has been used several times by the author to test the validity of this process in addition to using it in actual crime series analysis efforts.

In addition to the robbery series mentioned, PGM has been used in arson, burglary, and theft crime series in the Phoenix and Glendale, Arizona jurisdictions by the author with success.

In the Video Bandit case, there was a visible pattern in the crime paths. The suspect seemed to return to the N 67^{th} Av. and W Camelback Rd area after committing 1-3 crimes elsewhere. He also hit several areas more than once along 4300 W McDowell Rd, 7400 W Thomas Rd, and 6700 W Camelback Rd.

For this series, the mean distance traveled between hits was 3.36 miles with a standard deviation of 1.08 miles. Since the mean is 3.36 miles, and the greatest distance from one hit to the next was 4.755 miles, 2.28 (Mean-1StDev) miles was chosen as the buffer distance and 3 buffer rings were created around the last crime in the series. A maximum distance of 6.84 miles from the last hit is well within the maximum distance this offender traveled from any of his hits *(Mean plus 2 Standard Deviations or 3.36+(2*1.08) or 5.52 miles).* Figure 3 shows the three-ring buffer from the tenth hit in the Video Bandit series.

In addition to the buffer from the last hit, it is necessary to determine where likely targets are located in the area. Many software applications are available that already have the business locations geocoded. They may cost as little as $150.00 for some products, and over $5000.00 per year for others. A lot of this information is already available from planning departments, city tax and licensing offices, or other government sources at no cost or a reduced rate. Each of these databases has some unique problem due to political and tax structure policies within a city government. The Internet can provide a free and easy solution to obtaining business addresses and names in a relatively short time period. The Yahoo Internet site makes a mapping application available at the "MyYahoo" home page. It allows the user to type in an address and locate businesses around any location. Since the basic center of the crimes is N 51^{st} Av. and W Indian School Rd, this address can be used to get a map of the location. Once the map is obtained, there is a hyperlink text item to the right of the map that reads, "Nearby Businesses." Clicking on this brings up another page that allows a search by types of businesses or which contain some text. Typing in "video store" in this screen provides the results shown in figure 4.

The data on this website can be copied and pasted into an Excel worksheet and a new file ready for geocoding can be created. There is some formatting that must be done on the data to get rid of the backgrounds, lines, and colors, however it is relatively quick and easy to do in Excel.

Once the data has been geocoded, a shapefile of the video stores in the area is created. Once you have done this a few times, 200-500 business addresses can be easily added to the analysis from the Internet in less than thirty minutes. Obtaining business addresses from the Yahoo map site is not entirely accurate, but barring payment of several hundred dollars for an accurate business-listing product, this works quit acceptably. It often takes searching several key words, and perhaps several different address locations to get most of the businesses applicable to a large area.

At this point you should also add in the land use or zoning and census tract data files that are a good addition to the analysis. Due to space limitations, these datasets will not be discussed in detail here. In each jurisdiction, the elements and information may differ slightly in format and since we know this particular suspect is only targeting video stores, it is not as useful. When the suspect is striking against businesses seemingly at random, with no regard for type of business, the land use/zoning and census tract information can assist in specifying a certain geographic characteristic where a potential target might be located.

The Scoring Process to Predict the Eleventh Crime

The probability grid is scored on where the grids are located in relationship to the data elements previously described (see Appendix A). The spatial items scored at this point include;

1) Whether a grid is inside the minimum convex Hull polygon
2) A grid is within the probability rectangles and/or the SD ellipses
3) A grid is within the last hit buffer areas
4) Which grids are in the direction from the last hit as the path analysis suggests.

Once the grid has been "scored," and a standard deviation legend classification is applied, a more useful product map can be provided to the investigators and users of the information (figure 5). Figure 5 shows an area in red (95th percentile) where the suspect is most likely to commit his next crime in this series. This area is a much smaller geographic area than those identified with the standard statistical methods alone. These red grids represent those grids where the total score was greater than 2 standard deviations above the mean for all grids in the probability grid layer. Of course, the assumption that the offender will continue to behave in the manner in which he has previously done is vital to the success of this prediction. An interesting fact is that the number of targets in the “high chance” (68%) and “very high chance” (95%) areas are now reduced to 14 potential targets instead of the 27 or 21 targets identified with the SD ellipses or rectangles alone. This is still a great deal of targets, but much less than with either method alone.

The actual number of potential targets can be reduced even further by adding scores for:

1) Targets available in a grid
2) Repeat victimization within a grid.

Once these two fields have been scored you can recreate the map. The final map (figure 6) demonstrates that the potential target area for the next hit is reduced even more. The red grid (very high chance or 95th percentile) on the map contains only two potential targets, 6702 W Camelback Rd and 5104 N 67th Av. Applying this final analysis and selecting the potential targets in the 68th percentile and 95th percentile areas, highlights 12 most probable video store locations where the suspect might hit in his next offense. The two stores at 6702 W Camelback Rd and 5104 N 67th Avenue are the most likely targets this suspect will choose based on our PGM analysis effort. Investigators could operationally deal with 2 stores for undercover deployment activities, and perhaps even the 12 stores in the 95th percentile area.

Using the probability grid process and combining logically obtained geographic information with statistical methods, the potential targets in this analysis were reduced from 26 to 12 (This is a *significant reduction in targets for the investigators)*. In addition, this analysis made one area much more observable as a potential area of concern for the next hit in the series (67th Av & Camelback Rd). This grid contains the video store that the suspect hit in his eleventh armed robbery (6702 W Camelback Rd). This video store is in the list of twelve potential targets revealed by the probability grid method and is one of two stores identified in the "highest" probability grid. The tests of this method in actually scenarios have provided a satisfactory success rate at predicting the next target in a crime series. The actual use of this method in the Video Bandit series did encounter a few obstacles.

The Actual Scenario

On April 10, 2001 a bulletin was created and sent out to the Phoenix detectives indicating that the suspect may hit one of 12 video stores. There was an emphasis on the area of 67th Avenue and Camelback Rd. Information regarding the potential dates and times of the next hit were also included. The suspect was predicted to hit within 48hrs of our report. This bulletin was only provided to the Phoenix Police Robbery Detail at the time. The night after the analysis was released, the suspect committed his next crime at 6702 W Camelback Rd. During this offense, a witness tried to chase after him and was killed by the suspect. At that time the Phoenix Robbery Detail detectives did have two potential leads in the case, however within a few days after this last robbery and murder, the leads were dismissed as likely suspects. Since the last offense occurred in Glendale, Arizona, the Glendale Homicide Unit also began working the case and were provided with the second analysis the Phoenix Crime Analysis Unit Created. In this new analysis, CrimeStat's journey to crime (JTC) routine was also applied to ascertain the likely offender home address. The only other information available was that the suspect was a White or Hispanic male, and in several cases he was seen leaving the area in a red Saturn vehicle.

Journey To Crime (JTC) Worked

Initially field interrogations, citation data, and other databases were searched. At least 355 people who had driven a red vehicle or a Saturn, and who matched the general description of the offender, were found. Since the reported residence location and the offense location for several thousand offenders was available, this data provided the basis for calibrating the JTC routines in CrimeStat.

Figure 7 shows the best result from the JTC routines. Although the suspect's residence was not inside the "highest" probability area, it was still in the 1 to 2 standard deviations above the mean area for this series. What was important about the JTC routine was that it reduced the number of possible suspects who had been in a red car or Saturn from 355 to 54 potential suspects. The suspect in this case actually had a felony warrant for his arrest and appeared in the *(citation, field interrogations, and wanted persons)* data three different times. He also had been driving two different red Saturn vehicles. In the beginning of the series, the suspect also used a .22 caliber rifle to commit the crimes and later turned to a semi-automatic handgun and a shotgun. When reviewing the felony warrant information and reports, he was found to be on probation for a "drive-by" shooting in which a small caliber rifle may have been used. This was enough information to provide his name and information to investigators along with 7 other subjects out of the 54, who had records for armed robbery or violent offenses. The suspect was identified as the "most" likely suspect from the 8 for the investigators. Within days, the Glendale Police Department Homicide unit picked up the suspect at his home and found evidence of the robberies and the homicide in his home.

Conclusion

Although this is only one example and demonstration of the probability grid method, it is proving to be easy to create, more efficient than one conventional method alone, and allows the crime analyst's experience and knowledge to play a part as well. Once practiced and applied, the probability grid method does not take any longer to create and provides a more efficient operational estimate of the offender's next crime location.

The hope is that this paper and presentation will cause other analysts to try this procedure and improve upon the process for their jurisdiction. It does provide an operationally useful crime mapping product for tactical crime analysis.

The probability grid method has flaws as with any other method currently in use by analysts across the country. The probability grid method utilizes two common spatial statistical methods, combines them with basic geographic relationships, and intuitive knowledge of the investigators and crime analysts involved in a case. This process may also encourage analysts to track experience-related, decision-making data so that it can be quantified and collected to assist academics in creating better statistical models. PGM also allows for easy modifications, as needed, dependent on the circumstances surrounding a series of crimes. It can also be made to adapt to changes in the suspect's pattern as needed, because it doesn't rely on just one method, but is a combination of methods and analytical thinking based on spatial relationships and crime patterns or behavior.

As with any analysis effort to predict human nature, the suspect has to cooperate with the analyst and continue to be consistent in his criminal behavior. Since this is not always possible, this analysis method may also yield "bad" or inaccurate results in some crime series projects. It is reasonable to assume that if one method has attributes that make it effective and another method also has similar attributes, combining them may provide a better product as long as it is timely, and consistently performed by the analyst. If the analyst uses sloppy technique and is not consistent in applying this method, it is also assumed that the resulting product will likely lack validity and value.

Statistical analysis processes such as probability rectangles, convex Hull polygons, and standard deviational ellipses have proven successful for many analysts. An analyst's expertise has been recognized to be at least as effective as some statistical tools. Knowing this, combining the "best of both worlds" in the probability grid method allows the practicing analyst to gain a better foothold in the battle against serial crime in their jurisdictions.

Additional research and functions such as vector analysis, nearest neighbor, K means, kriging, and lag variograms should also be investigated as additional products that may provide better accuracy in the predictive model called "the probability grid method."

Further research and improvements to this method should be entertained from other analysts and academics wishing to test its ability to perform in a wide variety of cases. Experimentation by other analysts in their own jurisdictions and with their own data is vital to validating PGM as a useful tool for crime analysts. The author will collect any information provided on failures, successes, problems, additional analysis factors to include, and objective comments concerning this method from any analyst or academic who may apply it in the future.

Please contact the author, Bryan Hill at (623) 930-3073 or email at bhill@ci.glendale.az.us with any comments or suggestions concerning this method.

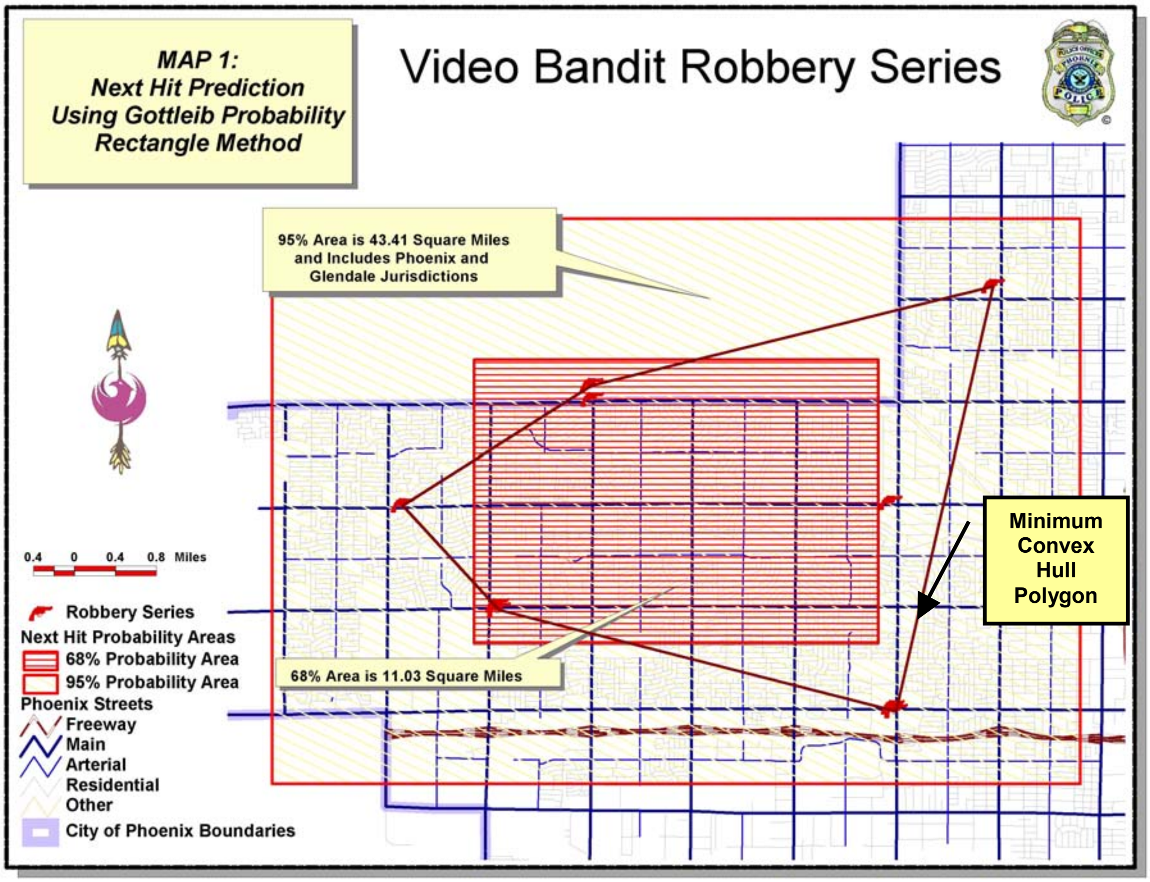


Figure 1
Video Bandit or .22 Rifle Bandit Robbery Crime Series in Phoenix and Glendale, Arizona
(1999 and 2000)

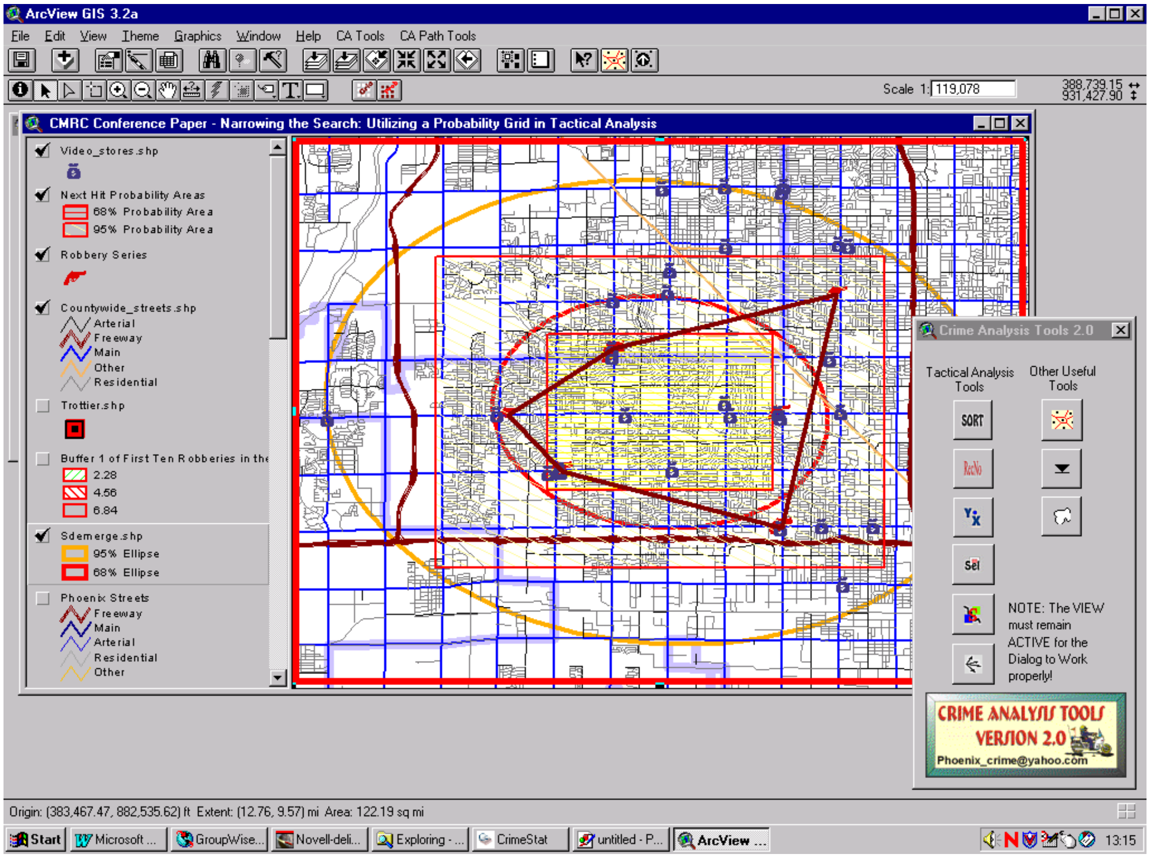


Figure 2

Statistical elements used in the Probability Grid Method

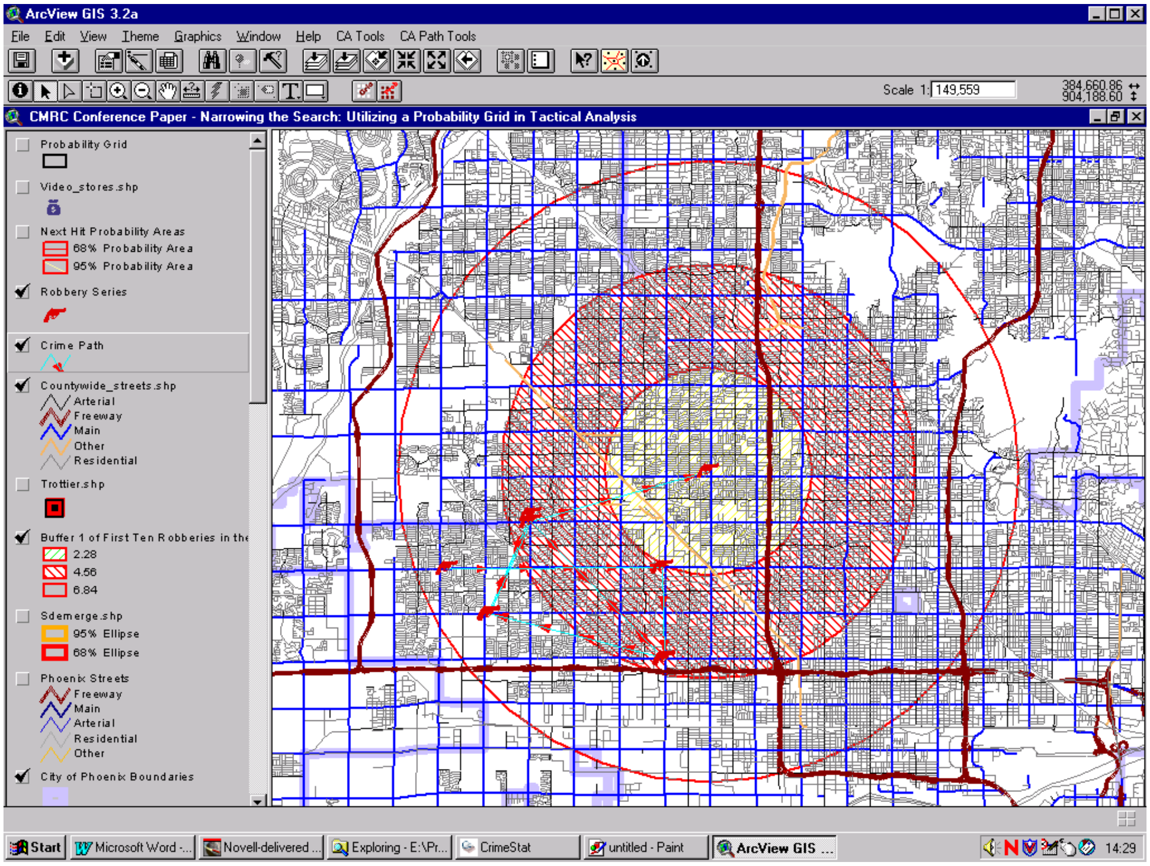
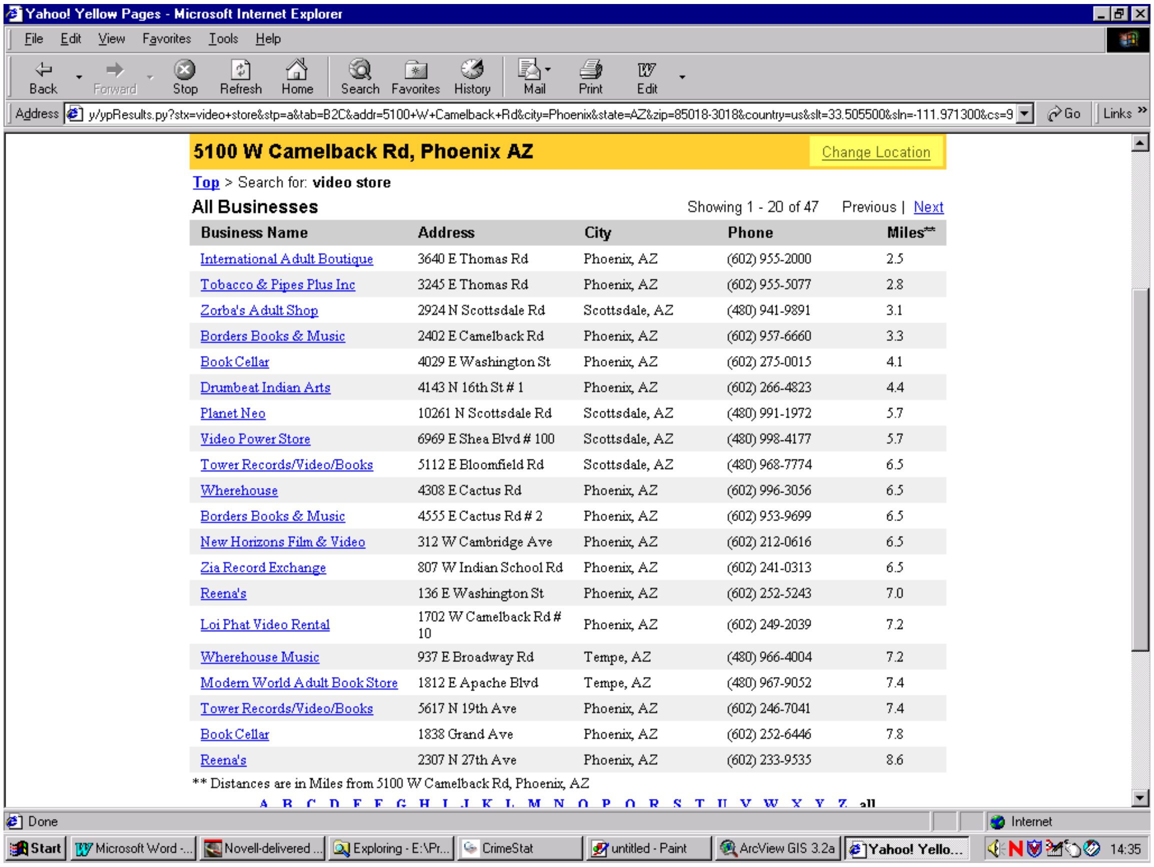


Figure 3
Last hit buffer rings



Yahoo! Yellow Pages - Microsoft Internet Explorer

5100 W Camelback Rd, Phoenix AZ Change Location

Top > Search for: **video store**

All Businesses Showing 1 - 20 of 47 Previous | Next

Business Name	Address	City	Phone	Miles**
International Adult Boutique	3640 E Thomas Rd	Phoenix, AZ	(602) 955-2000	2.5
Tobacco & Pipes Plus Inc	3245 E Thomas Rd	Phoenix, AZ	(602) 955-5077	2.8
Zorba's Adult Shop	2924 N Scottsdale Rd	Scottsdale, AZ	(480) 941-9891	3.1
Borders Books & Music	2402 E Camelback Rd	Phoenix, AZ	(602) 957-6660	3.3
Book Cellar	4029 E Washington St	Phoenix, AZ	(602) 275-0015	4.1
Drumbeat Indian Arts	4143 N 16th St # 1	Phoenix, AZ	(602) 266-4823	4.4
Planet Neo	10261 N Scottsdale Rd	Scottsdale, AZ	(480) 991-1972	5.7
Video Power Store	6969 E Shea Blvd # 100	Scottsdale, AZ	(480) 998-4177	5.7
Tower Records/Video/Books	5112 E Bloomfield Rd	Scottsdale, AZ	(480) 968-7774	6.5
Wherehouse	4308 E Cactus Rd	Phoenix, AZ	(602) 996-3056	6.5
Borders Books & Music	4555 E Cactus Rd # 2	Phoenix, AZ	(602) 953-9699	6.5
New Horizons Film & Video	312 W Cambridge Ave	Phoenix, AZ	(602) 212-0616	6.5
Zia Record Exchange	807 W Indian School Rd	Phoenix, AZ	(602) 241-0313	6.5
Reena's	136 E Washington St	Phoenix, AZ	(602) 252-5243	7.0
Loi Phat Video Rental	1702 W Camelback Rd # 10	Phoenix, AZ	(602) 249-2039	7.2
Wherehouse Music	937 E Broadway Rd	Tempe, AZ	(480) 966-4004	7.2
Modern World Adult Book Store	1812 E Apache Blvd	Tempe, AZ	(480) 967-9052	7.4
Tower Records/Video/Books	5617 N 19th Ave	Phoenix, AZ	(602) 246-7041	7.4
Book Cellar	1838 Grand Ave	Phoenix, AZ	(602) 252-6446	7.8
Reena's	2307 N 27th Ave	Phoenix, AZ	(602) 233-9535	8.6

** Distances are in Miles from 5100 W Camelback Rd, Phoenix, AZ

Figure 4
Yahoo business locator results

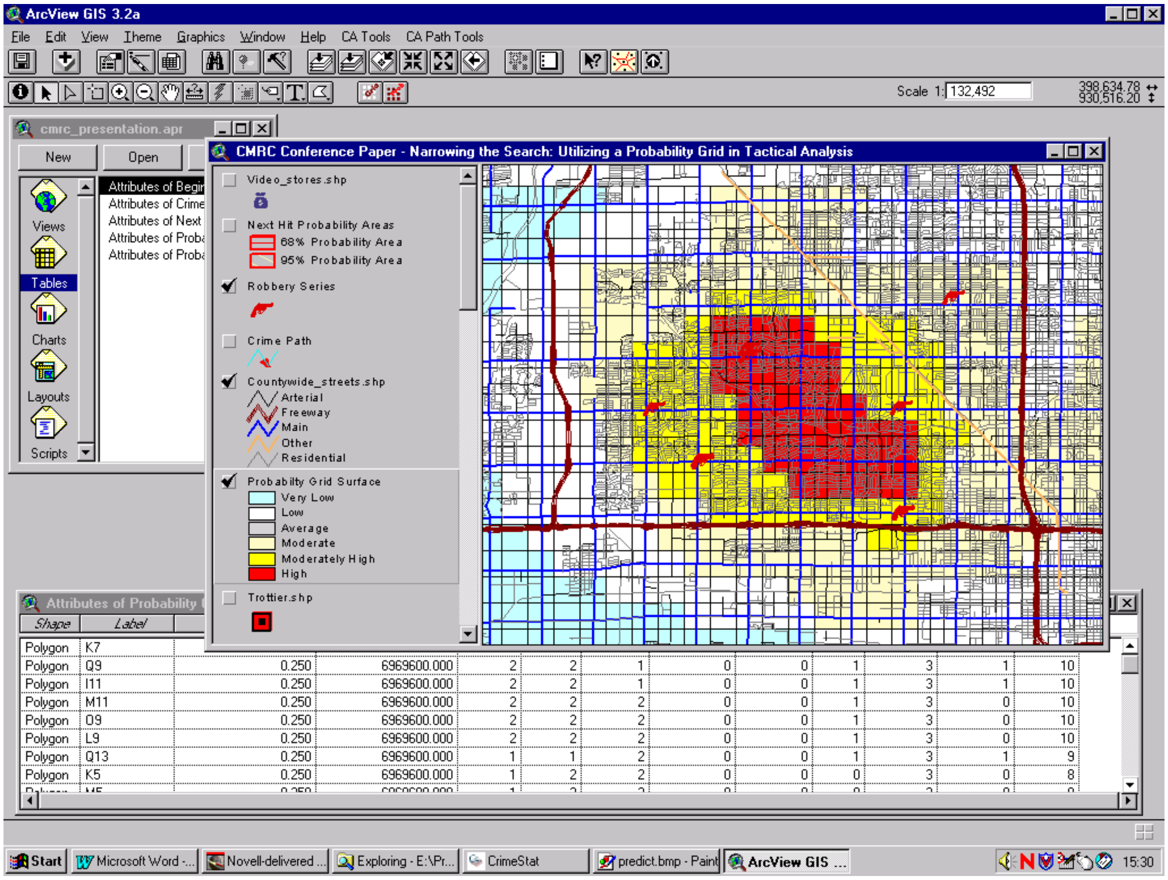


Figure 5

Statistical methods and first sub-totaling of PGM criteria completed

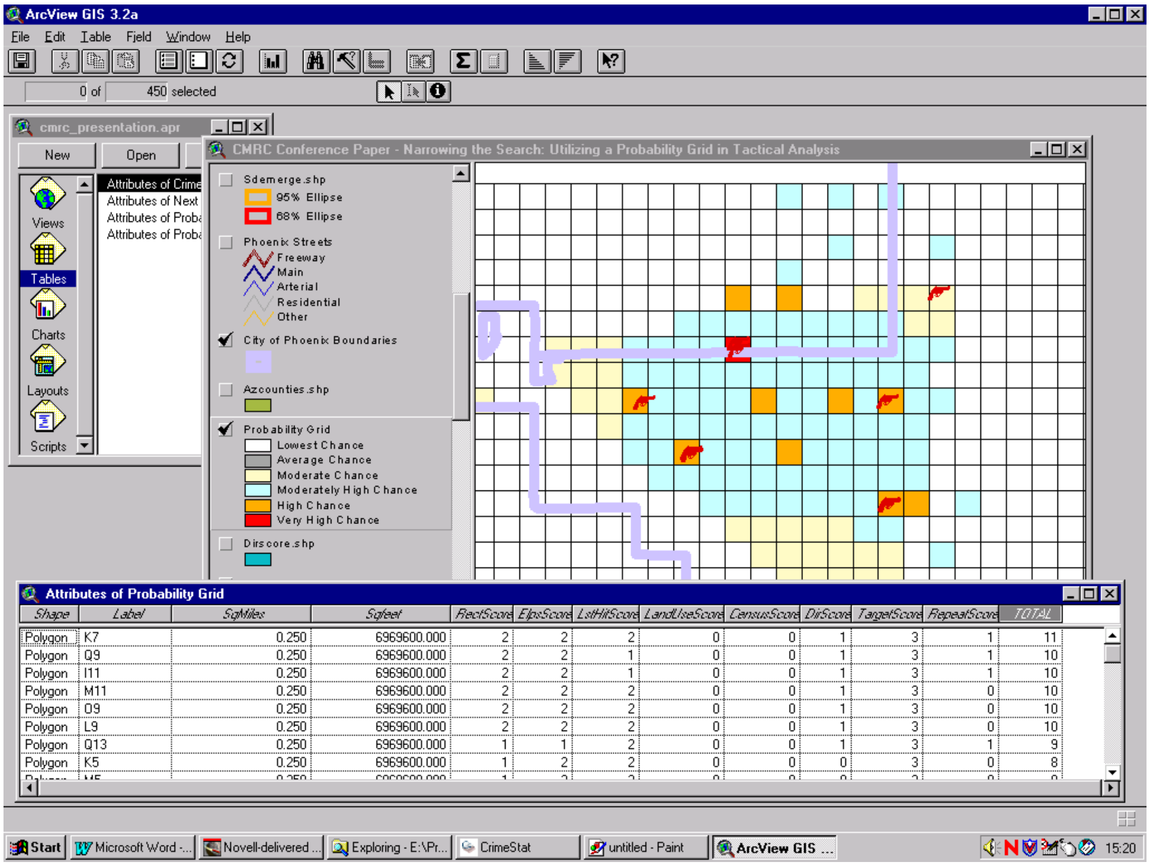


Figure 6

The final PGM prediction, one grid is the "most likely!"

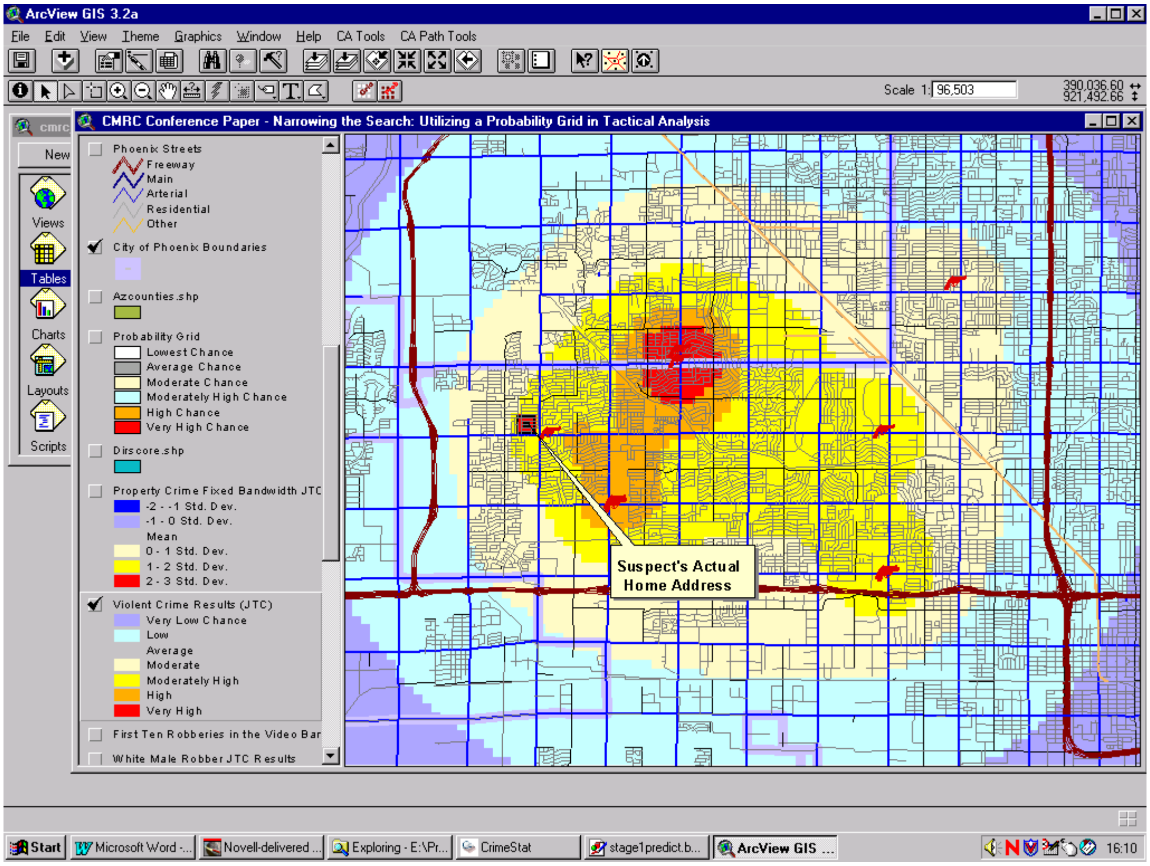


Figure 7
Journey to Crime Analysis results using CrimeStat

[1] Bryan Hill retired from the Phoenix Police Department after 21 years of service and is currently working as a civilian Crime Analyst with the Crime Analysis Unit, Support Services Bureau, Glendale Police Department, 6835 N 57th Drive, Glendale, Arizona 85301, (623) 930-3073, bhill@ci.glendale.az.us.

[2] Gottlieb, S., Arenberg, S. and Singh, R. *Crime Analysis: From First Report to Final Arrest*, Montclair: Alpha. (1994)

[3] The Blue Bandits were a group of black male suspects that hit various supermarket chains in Phoenix, Tucson, various towns in California, and possibly Nevada. Their basic M.O. was to enter a store with weapons drawn, threaten to kill anyone that did not comply, and then empty cash registers and safes as opportunity allowed. Their signature item was that they always wore either blue or red bandannas during the commission of the robberies. These suspects discontinued their robberies in the Metro-Phoenix area and are believed to be in custody on other charges in another jurisdiction. These cases is still open in Phoenix.

[4] The Super Sonic robbery series involved a lone black male who initially targeted Sonic fast food restaurants. This suspect always brandished a chrome weapon, wore a black ski mask, and his typical M.O. was to confront store employees at closing time or in the parking lot as they were leaving with the cash deposits for the day. This suspect was identified by cellular phone use logs form a victim's telephone stolen in a robbery, and arrested by Phoenix Police.

[5] This was a group of 4-5 Hispanic males that were robbing Mexican fast food restaurants in the Phoenix area. Their basic M.O. was to confront employees inside the restaurant, demand money and threaten with a knife if their demands were not met. These suspects were identified through photo surveillance equipment and witness identification of the offenders to Phoenix Police and arrested.

[6]Levine, Ned *CrimeStat: A Spatial Statistics Program for the Analysis of Crime Incident Locations* (v 1.1).
Ned Levine & Associates Annandale, VA and the National Institute of Justice, Washington, DC. (July 2000), NIJ Grant 97-IJ-CX-0040 and 99-CX-IJ-0044.

[7] Paul Catalano is a postgraduate student at the University of Western Australia conducting research on the geographic behavior of serial offenders. paulwcat@altavista.net

[8] Brennan Long is a Criminal Intelligence Analyst with the Organized Crime Bureau, Phoenix Police Department, 620 W Washington St, Phoenix, AZ 85003, analyz007@hotmail.com

[9]Dan Helms is a Crime Analyst with the Las Vegas Police Department, Las Vegas, NV and author of several papers on advanced spatial analysis techniques related to tactical crime analysis. Contact Mr. Helms for copies of his papers and research relating to advanced methods. d5217h@lvmpd.com

[10] Catalano, P.W., Hill, B and Long, B, 2001, *"Geographical analysis and serial crime investigation: A case study of armed robbery in Phoenix, Arizona"*, Security Journal, 14(3):27-41.

[11]Rossmo, D.K. (1995a) *Overview: Multivariate spatial profiles as a tool in crime investigation*. In: Block, R, Dabdoub, M and Fregly, S. (eds*) Crime Analysis Through Computer Mapping*. Washington DC: Police Executive Research Forum; Rossmo, D.K. (1995b) *Place, space and police investigations: Hunting serial violent criminals*. In: Eck, J.E. and Weisburd, D. (eds) *Crime and Place*. Monsy, NY: Criminal Justice; Rossmo, D.K. (1997) Geographic profiling. In: Jackson. J.L. and Bekerian, D.A. (eds) *Offender Profiling Theory, Research and Practice*. Chichester: John Wiley.

[12]Environmental Systems Research Institute (ESRI) is a vendor of the ArcView GIS software and other related GIS mapping applications. www.esri.com

[13]The Omega Group has created a crime analysis extension to ArcView called Crime View which allows the user to make incident queries, person queries, and other crime analysis queries on their own data in an easy to use format. www.theomegagroup.com

[14] Bailey, Trevor C. and Catrell, Anthony C. *Interactive Spatial Data Analysis*, Longman Group Limited, 1995:183

[15] *Bryan Hill is currently experimenting with creating a JTC probability grid that also combines several JTC processes in a similar manner as the PGM process. He usually runs all of the mathematical JTC routines offered in CrimeStat, as well as a data calibrated routine and then combine the results into one grid theme. He has also calculated the average distance offender's travel to commit crimes in this jurisdiction and adds a buffer around the mean center of the incidents and score the JTC grid higher for that area as well. Combining these methods may be more useful than one method alone, however it has only been used on two crime series, and hasn't improved identification of suspects in any crime series. The limitation in using a JTC analysis is that the agency using it must have a large amount of detailed "person" data to query once the probable areas are identified. This data search may involve a great deal of time, and may not be operationally useful if the suspect description is vague or limited.*