Project CO-OP

Computerized Officer Operations Placement

New Mexico Supercomputing Challenge

Final Report

April 8, 2020

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Project Computerized Officer-Operations Placement

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Executive Summary

Crime is a serious problem that has plagued New Mexico for decades [1], and is still an issue that needs to be dealt with. Solutions such as training and deploying more officers are a temporary solution and extremely costly. The average cost of a police officer is nearly $149,362 with supervision [2], making it an expensive solution, especially for a financially limited state such as New Mexico. The best way to address crime is to raise more people out of poverty, educate more people, and improve the economy, but until long-term solutions are put into place crime will remain high while resources for police departments are limited. Considering this, every police officer serving is a valuable asset and should be used as effectively as possible to increase performance.

To address this, our team has created a model which forecasts and weighs crime, then places officers where they would be most effective based on forecasted data. The model works in four parts. First, it collects data on crime, including the location and the time of occurrence, as well as what happened. It then forecasts the possible crime rates based on the collected data, and then determines the best place to position police officers. Finally, it displays the predicted crime and proposed officer locations on a map. This offers a temporary solution to addressing high crime rates and rising response times whilst more advanced and long term solutions are created.

Introduction

Albuquerque is the largest city in New Mexico and houses more than a quarter of the state's population. It is notorious for having an extremely high crime rate and an abysmal police response time, which averaged 48 minutes in 2019.[3,4,5]. Out of all the population centers in New Mexico, Albuquerque was ranked the fourth highest in crime rate in 2018 [6]. In recent years, the city reported a slight decrease in crime but their crime rate continues to remain extremely high. While Albuquerque may be seeing small declines in crime rate, New Mexico continues to have a rising crime rate which is seriously impacting the state. Crime makes New Mexico an undesirable state to invest money into and thus stunts economic growth which contributes to other issues such as declining highschool graduation rates, poverty, and ultimately more crime [7]. By addressing these issues, New Mexico could see public health improve by a significant amount [8,9].

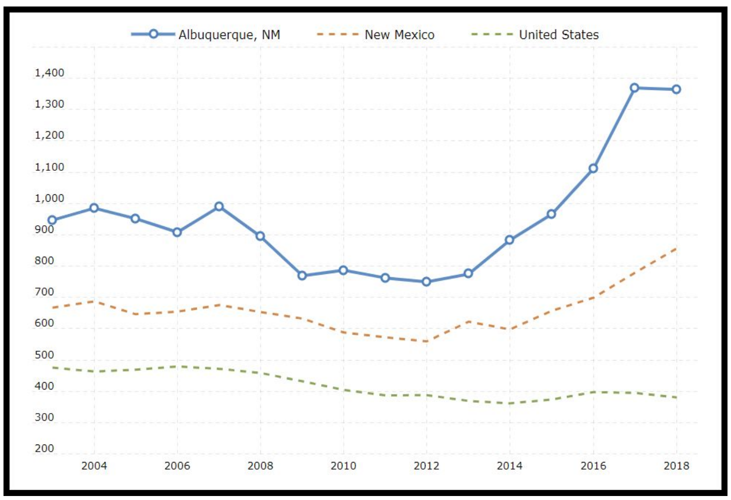


Figure 1: A graph of the violent crime rates of the United States, Albuquerque, and New Mexico from 2003-2018. (macrotrends.net)

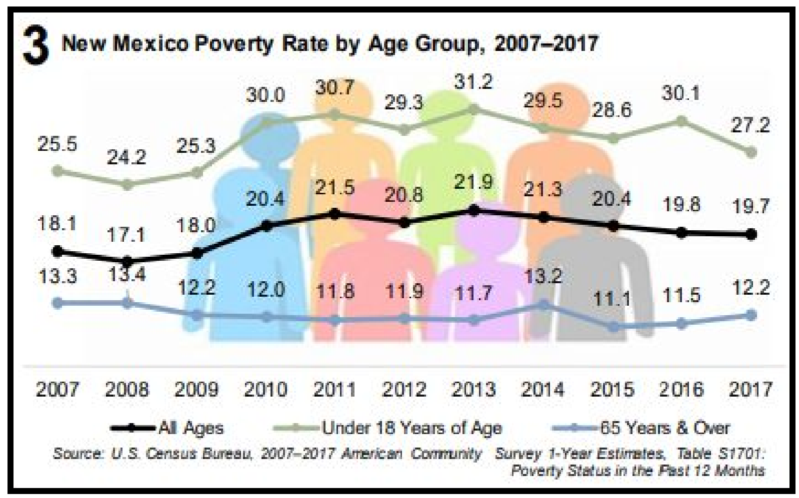


Figure 2: A graph of poverty rates by age group from 2007-2017 (New Mexico Department of Workforce Solutions)

Crime rates in Albuquerque, New Mexico, remain astoundingly high, despite a decreasing national crime rate (Figure 1). As a state, New Mexico has seen a surge of crime in recent years as well. Poverty rates in New Mexico remain high but have seen slight decline overall (Figure 2). New Mexico's economic situation does not help either- New Mexico was ranked 38th in the nation for GDP in 2015 with around $86,000,000,000 and that position hasn't changed since then [10].

A high crime rate has made Albuquerque a worse place to live. It has hurt the city's economy and has tarnished its reputation as a whole. Crime is a complicated issue, and there is no simple solution to Albuquerque's high crime rate. The city does not have the resources or budget to hire enough police officers [11], which is a costly endeavor and thus needs a better solution for its high crime rate [12]. Our solution to this problem is crime mapping [13].

Crime mapping is the act of recording the location of crimes and displaying them visually on a map to detect patterns from them. This helps the police force do a better job at stationing police officers [14].

This solution is based on the "broken window theory" which explains why crime is concentrated in localized areas. The broken window theory is the idea that if crime occurs in an area, and is not addressed, it will spiral out of control. This theory was supported by an experiment run by Philip Zimbardo in 1969, where he abandoned two cars on the side of the road in two cities. In one, the car was destroyed very quickly, and stripped for its parts. On the other, though, the car sat there until Zimbardo eventually damaged it. After the car was damaged, it was then destroyed very quickly afterward. This chain of effects supported the broken window theory. [15] Even if the broken window theory was not entirely correct, it supports the idea that crime springs from other crimes, which is what our model is based on.

Method

In order to address the high rate of crime in Albuquerque, we have created an interactive crime map which models likely areas of crime and, based on its prediction, suggests where police officers/patrolmen should be placed in order to better ensure the safety of the community as a whole and cut down on response times. Crime rates in Albuquerque have been a major issue for years. Our solution to alleviating this problem involves using a crime map and forecasting to station police officers in the areas in which they are needed most. With this interactive crime map and model, we have a potential solution to decreasing Albuquerque's crime rate and police response times.

We first collect data on crime incidents in Albuquerque, then process this data and use it to fit a trend of crime rate. Based on this existing trend, we make a mathematical prediction of what the crime rate in the future of an area will be. Using this data, we find the areas of highest crime and place an officer in those areas. Finally, this data is exported to our visualization program. The visualization program imports the data and uses the Google Maps API to display the data and officer placement.

Data

Our data is from a single source that has been verified by the Albuquerque Police Force and the Real Time Crime Center in Albuquerque [16, 17]. Our source for crime data is crimemapping.com, which specializes in providing crime maps to civilians so that they may be informed about the crime rates of certain areas.

The data is put into a tab-delimited file formatted with the place address, the date and time of the issue, and the type of incident, which plays a role in how much "weight" a particular incident was given. During the prediction of crime, the address is converted to points in latitude and longitude using the Google Places API. To ensure that all addresses end up in the correct city, the city and state name is concatenated to the end of the address. The address uses the datetime Python library in order to get the day that an occurrence happened in a year. We do this by adding the number of days in all previous months together (including February 29, if it was a leap year, but omitting it if it wasn't) and then adding the number of days in the current month to it.

Model

When the user runs the model, they are presented with a GUI (Figure 3) that allows them to input a series of variables and files. These are inputs that the user will be able to change to ensure that their model best suits their city. The *city* variable is the city that the model will be run in. This ensures that all addresses end up in the correct city (for example, if an address is 800 Main St., the city needs to be placed onto the address, or this may end up in another city with 800 Main St.). The *Officer Count* variable represents the number of officers to be placed in the model. The default is 100, but this can be changed, depending on police force size. The *Default Weight* variable has the weight for an incident that is not documented in the Crime Weight File. In the example shown in Figure 3, if the incident type "robbery" was not given a weight in the file *weights.txt*, the weight for a robbery would be 50. This can be changed based on what the most prominent crime type

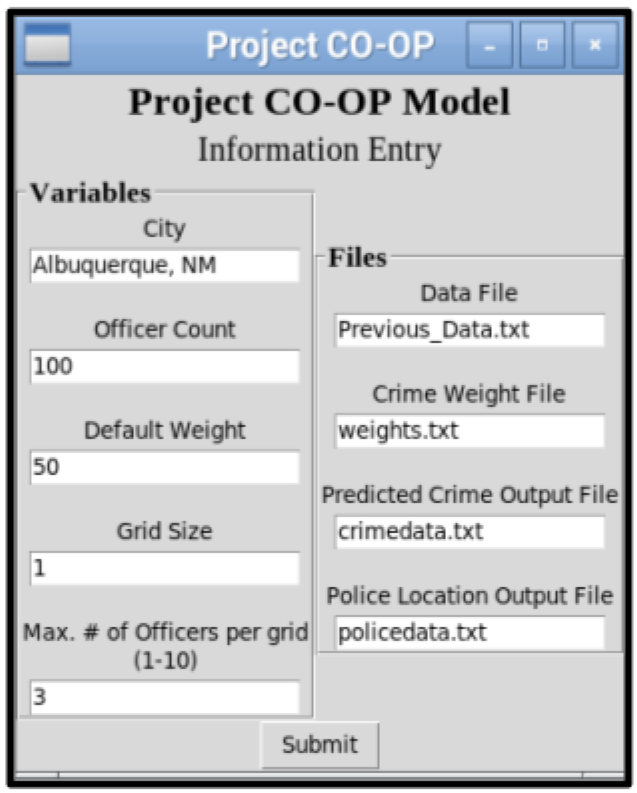


Figure 3: The user interface shown upon execution of the program. It has options for variables and files.

in the city is. When running our model, the default weight is set to 50, signifying that all undefined weights will be defaulted to the weight of a violent crime. The variable *Grid Size* indicates how large (in meters) the grid to place officers in should be. The variable *Max # of Officers per Grid* indicates how many officers should be placed to patrol in one grid area. The maximum value this variable can be is 10.

The files inputs allow the user to add their own files as the input and output files. The *Data File* is the tab-delimited data file where the crime data is placed, containing address, time, and incident type. The *Crime Weight File* is an input file where a crime type is accompanied by a weight that the crime type should be given. Most crime types should be identified here, but if one is missed, the *Default Weight* will default the weight of that particular crime to its value. The *Predicted Crime Output File* is the output data file containing a list of latitudes and longitudes and the weight each one should have. This file is used to map the crime data as well as calculate where the locations of police officers should be. The *Police Location Output File* is the file that maps the latitudes and longitudes of the calculated police locations. The default value of both output files is the necessary name scheme for them when they are uploaded to the web map display. Once the variables and files have been input, the forecasting program runs, and a progress bar appears to show the user how long is remaining in the place initialization. This can sometimes take a long amount of time, so the progress bar is able to tell the user how much of the data file has been initialized. Once the forecasting program has exported its file, the officer placement program runs using the file from the forecasting program. The officer placement program will then export a file that contains the best positioning of officers. These two files can then be uploaded to our website in order to visualize the data as a heatmap, with points overlaid for where officers should be placed for maximum efficiency (Figure 4).

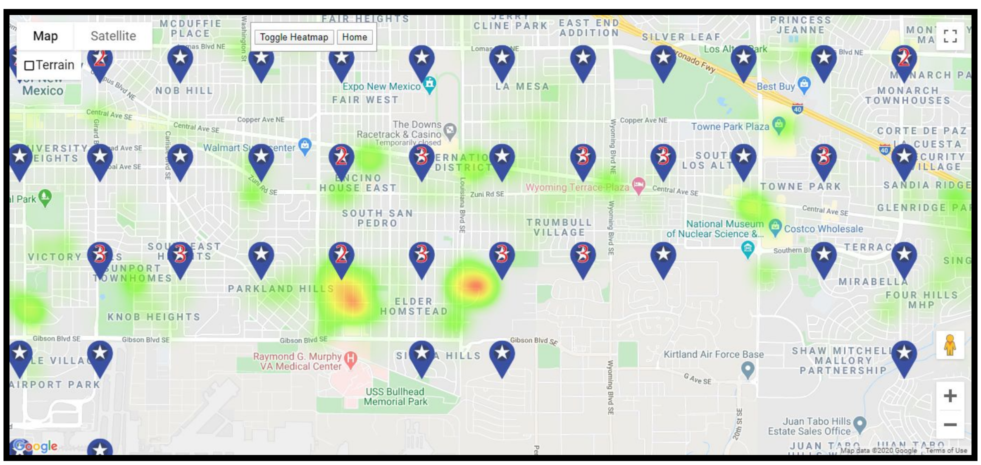


Figure 4: An example heatmap with officer points overlaid in places where they would be most efficient. Numbers indicate how many officers should be positioned in an area.

Forecasting

In order to forecast crime, a method of curve fitting is used. Crime can follow a number of patterns, so in order to try to accurately predict it, we have to consider that sometimes crime can increase in an area, and that could lead to a trend of rising crime rate through the broken window effect [18,19]. Crime tends to appear in areas of high crime rate. In order to forecast crime, we consider past crime data.

Each crime is weighted differently in order to address more severe offenses with higher priority than less severe offenses. This cumulative weight for a day (the total weight of all crimes in an area) is considered the crime rate for that day. The rates over these days are then analyzed to get a trend of each area.

A number of functions are used in the analysis. The two prediction algorithms (referenced as Weighted Linear Regression and Recent Trend Analysis) both interpret data and attempt to predict the rate for the next day. If the prediction from these algorithms is averaged, a forecasted data point of greater accuracy is achieved. This forecasted data point is what is exported as the predicted next data point, and the officer placement is based off of this forecasted data.

Basic Algorithms

Basic functions are functions that did not actively place officers or predict crime rate in the model, but contain algorithms that are called in other functions. A map of the functions is shown in figure 5.

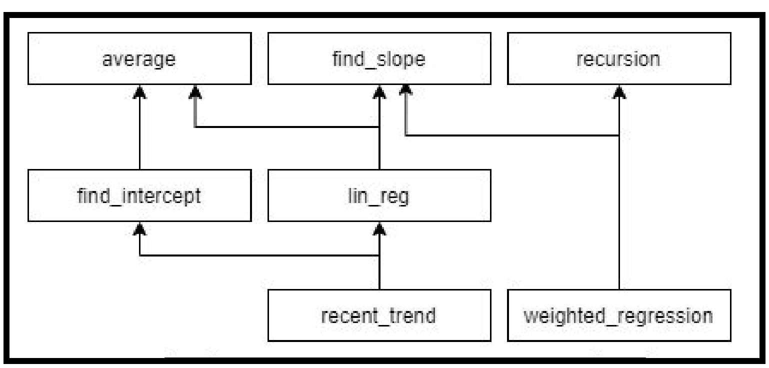


Figure 5: A map of the functions used in the prediction of the crime rate. Each rectangle represents a function, and arrow signifies that the function pointed to is called from the function that the arrow originated in.

The *average* function finds the average value of a set of values given in an iterator (an object that has multiple values that can be iterated, or looped, through).

The *find_slope* function finds the slope between two points, given as arguments *x1, y1, x2, y2*, where (x2, y2) is a point and (x1, y1) is another point.

The *recursion* function finds the sum of all of the values in an iterator.

The *find_intercept* function determines the y-intercept of a trend based on a series of points and the slope given as arguments. The slope line is plotted at the given x-values and then the corresponding y-values of the points are plotted. The average distance of the line from the series of y-values is returned as the y-intercept. The *average* function is used to find the average of the distances from the line.

The *lin_reg* function finds the linear regression of a series of points by finding the slope of all of the points using the *find_slope* function. It then returns the average of all of these slopes, which is given as the slope of the linear regression line. The *average* function is used to get the average of all of the slopes.

Weighted Linear Regression

The idea behind the Weighted Linear Regression is that a linear regression could be performed to see the general trend of the direction of the crime rate of an area over the span of the data. However, recent crimes could play a much larger role in the future of the crime of the area, thus the weighted linear regression will put higher weight on more recent data and crime incidents, but will still include older data and rates. We use the amount of days in order to determine the number of days that have elapsed since the occurrence, and therefore how much weight a particular point should be given.

The weighted linear regression works by finding the sum of all of the times that data is given for using the *recursion* function, using that to calculate the weight that a data point has, and adding them. The final crime rate for an area using this method is calculated as

$$\sum_{i=s}^{n} w_n(\frac{n}{t})$$

where s is the number of data points, w_n is the weight at the n time, and t is the total amount of time as calculated by the *recursion* function. This method gives a smaller fraction of the overall predicted weight to lower time quantities, and gives the highest fraction to the highest time quantity, which is also the most recent point.

Recent Trend Analysis

The recent trend analysis allows us to see how the crime rate has been progressing in an area recently. In some cases, crime may begin to drop off or increase because of some outside circumstances, but only very recently. The recent trend would see that drop and predict the crime based on that trend.

The recent trend looks at the most recent five data points (if there are 5 or more points) and runs a linear regression of them. It then reverses a data point and determines if the change from the previous point is ±0.05 of the rest of the trend. If so, that point is included in the linear regression, and it reverses back another data point, until the trend between two data points breaks the ±0.05 trend. The slope of this regression and the data points are then run through the *find_intercept* function to get a line. This line is used to predict the next data point.

Officer Placement Algorithm

The officer placement program uses the data exported from the forecasting program. The purpose of this program is to best place officers where they would be most efficient at finding and effectively handling crime. An algorithm will place officers in areas of highest predicted crime so as to try to prevent it from happening, or preparing for where it is most likely to happen.

The officer placement algorithm first takes in all of the data from the data file containing the forecast data. This file contains the total crime weight in all of the recorded addresses. The user inputs a resolution value, based on how large of an area crime rate should be calculated for. This creates a system where crime predictions are put in a grid, rather than in individual points and allows for less close range of officers. This resolution should take the officer's patrolling range into account; they are able to move as opposed to standing still.

The resolution is given in meters. The program then converts meters to degrees latitude and longitude (dividing by 102,470). The latitude and longitude values of each address are multiplied by the reciprocal of the resolution, shown below.

$$(lat(\frac{1}{resolution/102,470}), long(\frac{1}{resolution/102,470}))$$

The decimal is then removed from this number, so that areas that were within the same resolution distance would all be grouped together. Removing the decimal off of the new latitudes and longitudes allows for less accurate measurements, which will all be in the resolution distance. In the same resolution, nearby areas accumulate the total weight, as opposed to points in the same place all accumulating very different weights.

The program then finds the sum of all of the crime weights in the predicted file in the city (referred to hereinafter as the *total weight*). Then, it divides the total weight by the number of officers to be placed (hereinafter referenced as *weight per officer*) to determine how much weight, if all of the weights were in the same place, an officer would be expected to take on.

Then, each place is iterated through, and the officers are placed based on what the weight of a particular area is. For example, if an area had a weight of 50, and the weight per officer was 20, 2 officers would be placed in that area. However, the extra 10 weight was not included, so some officers will be left unplaced. After all of the places have had officers divided up amongst them, some places will have had less weight than the weight per officer, so they would not have any officers. The officers will be placed in the remaining places with no officers based on a raking system of high crime expectancy.

It should be noted that there is a parameter for the maximum number of officers in an area. An area can get up to this many officers, but cannot exceed this number. This way, there is a better distribution of officers, and an excessive number will not be placed in one area. The default maximum number of officers in an area possible is 10, but that value can be lowered by the user.

Visualization

To increase processing speed and program stability we chose to divide the interpretation of the data, and the processing of the heatmap into seperate programs. The visualization program consists of two major parts, the data interpreter, and the web display. They use a combination of php, and javascript to interpret and display our data.

Data Interpreter

The data interpreter uses php to extract the data and create a versatile web display using the Google Maps Api. The data interpreter begins by checking if the data files are present and if they are formatted properly. If a data file is not present or is not formatted, the program stops and returns an error according to our error table (Figure 6,7). Each error code contains two letters and one number.

Error Code (First 2 Letters)	Meaning	Explanation
FO	File Opening	Error while opening file
FW	File Writing	Error while writing to file
NF	Not Found	Error when locating file
WF	Wrong Format	Error when checking file format
UK	Unknown	Unknown error

Figure 6 (above): A table of the meanings of the first 2 characters of the error codes

File Code (Number)	File	Explanation
0	crimedata.txt	File that containts the crime data
1	policedata.txt	File that containts the police placement data
2	hotmap.html	File that displays the data
3	2020superlogo.png	Map marker image

Figure 7 (above): A table of the meanings of the last character of the error codes

For example error FO1 would mean an error occurred while opening the file policedata.txt. If there are no opening or locating errors, the program opens and writes the basic html and Google Maps API components to our heatmap file. If the program cannot write the heatmap file it returns a writing error. The program continues by tokenizing the police data file, and counts the number of lines. A for loop separates the data line by line and stores the longitudes, latitudes and the amount of officers into arrays. If the file is improperly formatted, the program stops and returns a formatting error. The arrays are then unpacked and written to the heatmap file in the Google Maps LatLng format, {position: new google.maps.LatLng(*longitude* , *latitude*), type : *officer_number*}. A second for loop repeats this process with the crime data file (crimedata.txt) using the Google Maps weighted location format, {position: new google.maps.LatLng(*longitude* , *latitude*), weight: *weight*}. The program then writes the closing html and Google Maps Api components to the heatmap file.

Web Display

The web display uses JavaScript and the Google Maps Api to display both the crime and officer placement data . The web display begins by loading the basic Google Maps library and the Visualization library. The display adds the police officer points to the map, and then adds the crime data points as a weighted heatmap layer. The effect the points have on the heatmap are determined by the weight of the point. Weights are determined by the severity of offence (Figure 8, 9).

Weight	**5**	**10**	**15**	**20**	**25**	**30**
Offence	Disturbance Direct Traffic Forgery Vandalism Loud Party Loud Music	Traffic Stop	Suspect Sighting Traffic Accident	Shoplifting	Drunk Driver Family Dispute Neighbor Trouble	Commercial Burglary

Figure 8 : Weights 5 through 30 and the offences that correspond to them.

35	**40**	**45**	**50**
Auto Burglary Missing Person Onsite Auto Theft Residential Burglary Car Jacking	Robbery Fight In Progress	Theft, Fraud, Embezzlement Narcotics	Rescue Call Shots Fired Aggravated Assault, Battery Armed Robbbery

Figure 9 : Weights 35 through 50 and the offences that correspond to them.

Results

Forecasting Verification

In order to determine the accuracy of our model against actual data, we ran a prediction using data spanning from March 9th to April 4th. We then were able to compare it to the actual April 5th and 6th data of crime in Albuquerque (Figure 10). The map shown in figure 11 shows the predicted crime area of data. In figure 12, the crime data points are overlaid over our heatmap prediction.

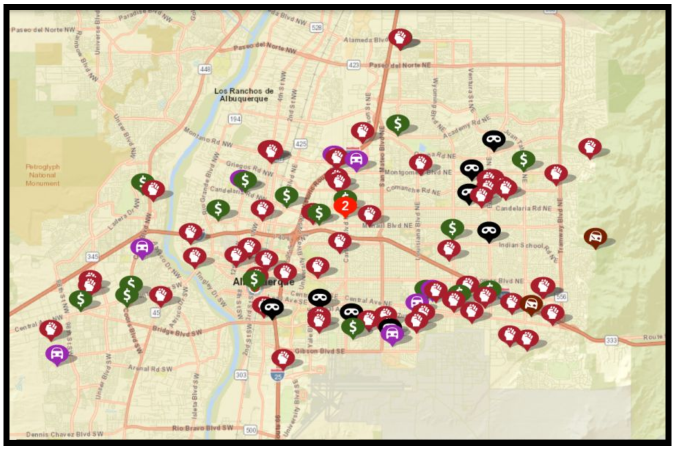


Figure 10: Crime Data from April 5th and 6th, with incidents overlayed on a map. Source: crimemapping.com

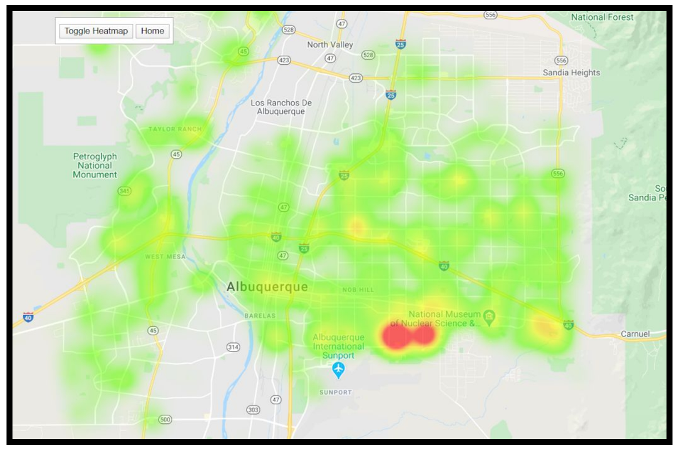


Figure 11: The heatmap of predicted areas of high crime.

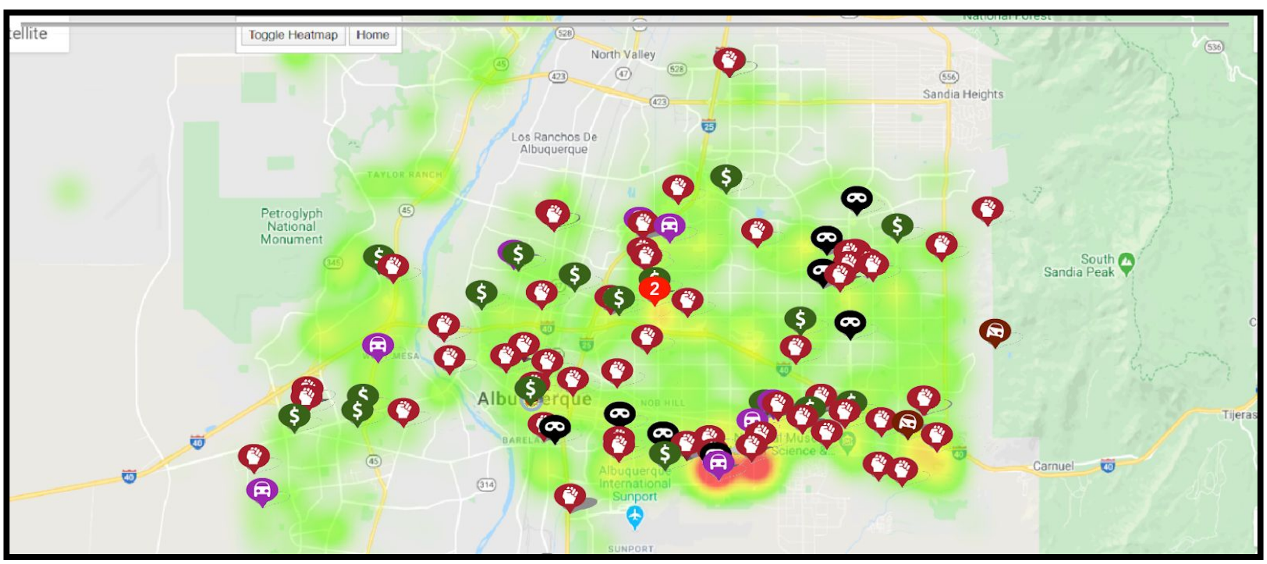


Figure 12: The data points retrieved from crimemapping.com overlaid on our heatmap prediction of high crime rates.

In verification of our model, much of the crime that happened was in an area of predicted high crime, and as a result, an officer would have been able to catch it. However, in some areas of predicted high crime expectancy there was not actually the resulting high crime. In these places, officers would be placed where not necessary. However, if data were collected over more time, it is likely that we would see crime start to follow a pattern of the prediction heatmap.

During this trial, we ran data for all crimes excluding disturbances of the peace and vandalism. In addition, while verifying, we compared data to that of all crimes excluding disturbances of the peace and vandalism. It should also be noted that the amount of crime measured recently has decreased significantly, and that might be due to the outbreak of COVID-19. The effects of the pandemic might be directly affecting the crime rate, as there are fewer people and businesses about, so less actual possibility for crime to occur, or it could be the law enforcement system being weakened by the pandemic, with fewer officers on the street and fewer officers willing to risk being infected thus lowering crime detection . [20,21]

Modelling Officer Placement

When the model was run with the parameters set to the default parameters, with the exception of *Officer Count* which was set to 365, the size of the operating police force, and *Grid Size* which was set to 1000 meters. The predicted model that was exported aligned well to the actual crime that happened at the time that the model was supposed to be modelling for. The officer placement made a high distribution of officers around the city of Albuquerque, with extra officers where crime was forecasted to be a prevalent issue, and no officers where no crime was predicted to occur. A section of the exported heatmap using these parameters is shown in figure 13.

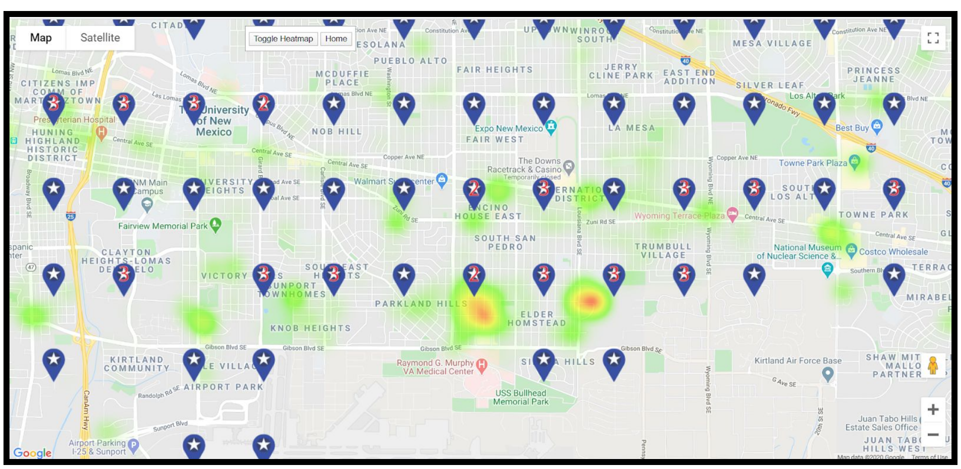


Figure 13: An example heatmap with officer placement. Parameters: default except *Officer Count* is set to 365 and *Grid Size* is set to 1000 meters.

When a lower *Grid Size* is set, (figure 15) weights stop taking into account nearby weights, and officers tend to build up excessively in some areas, which makes for inefficient placement and lack of officers in other needed areas. On the other hand, a higher *Grid Size* (figure 16) results in lower resolution, and an expectation for officers to patrol a larger area. Some areas may not be seen, effectively resulting in a similar situation to what is seen currently. In addition, areas with no crime will not get addressed, so not all officers will be placed because no crime existed for the places that are not covered, which leads to a much worse situation than what is currently seen. It is important to keep a reasonable officer patrol area in mind when setting resolution so that officers do not clump together and leave places totally vulnerable, but so that all officers are utilized and an officer is not expected to cover an area of ground that is not possible for them to cover.

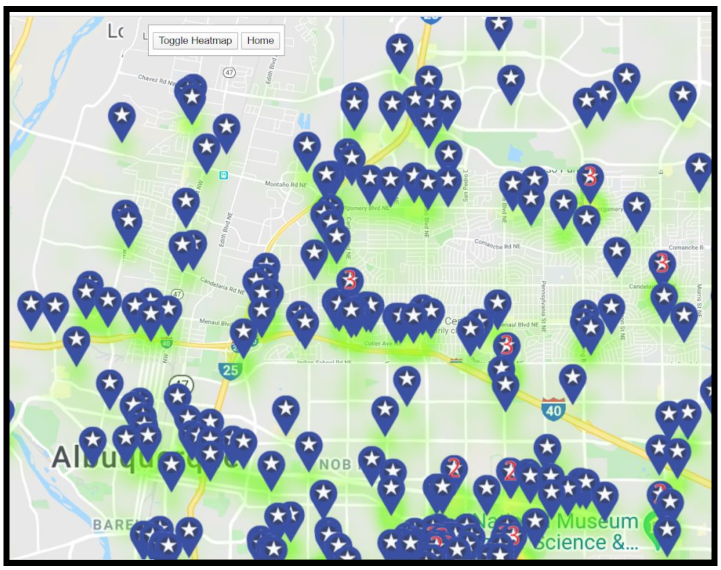


Figure 15 (above): Example heatmap with *Grid Size* set to 1 meter

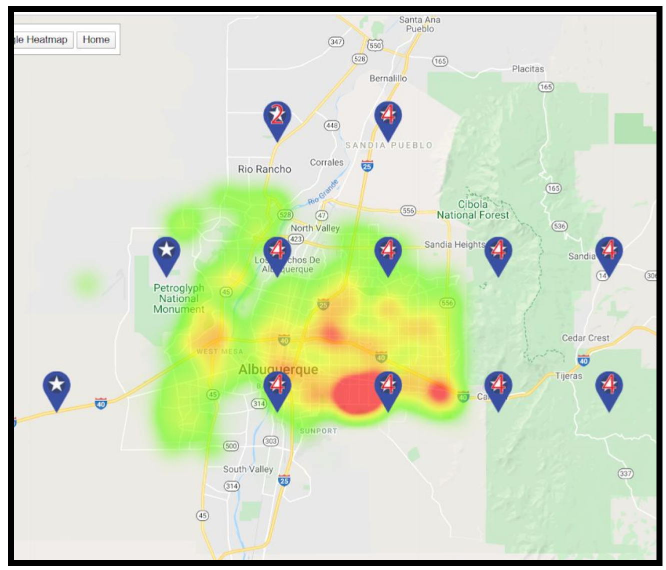


Figure 16 (above): Example heatmap with *Grid Size* set to 10,000 meters

Figure 17 (below): Example Heatmap with *Max # of Officers per Grid* set to 2

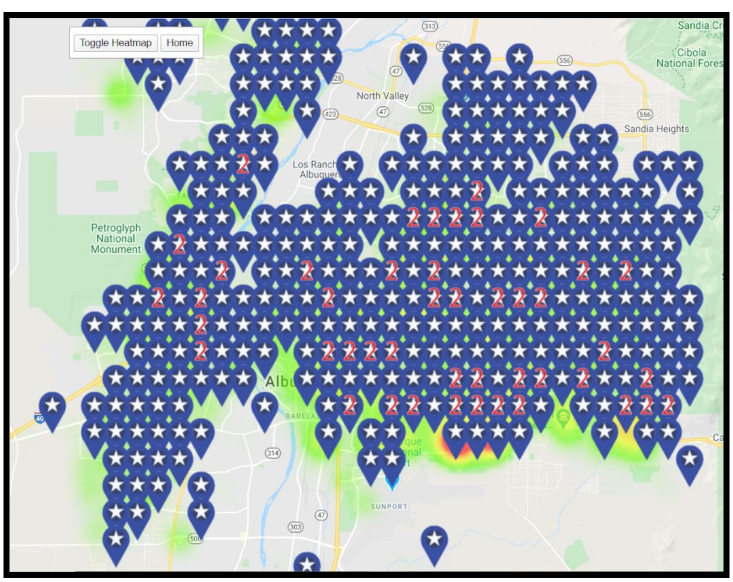
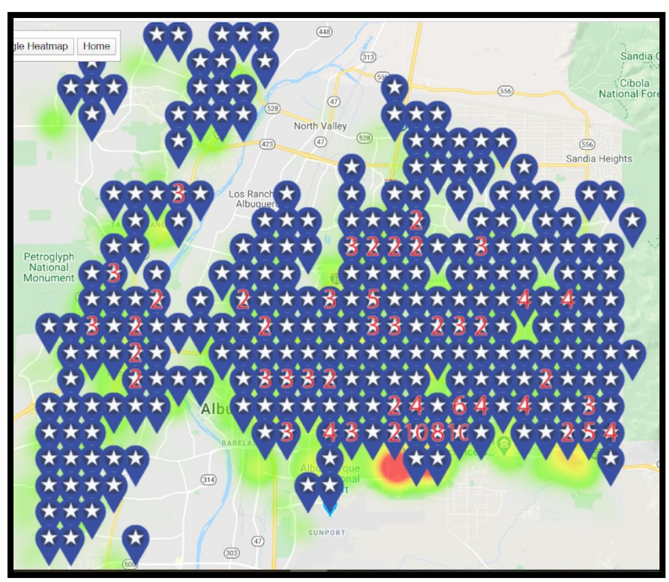


Figure 18 (below): Example Heatmap with *Max # of Officers per Grid* set to 1



When a lower *Max # of Officers per Grid* is set (Figure 17), then more officers can be placed around the city. However, there will be less support for an officer in an area of high crime rate. On the contrary, a higher *Max # of Officers per Grid* (Figure 18) will result in many officers being placed in areas of high crime, and there not being enough officers to be placed around the entire city. It is important to consider how many the best number of officers to place in a particular area would be, as it will keep the officers distributed and not all targeting one area, but supported enough in the case of a dangerous incident that could require more assistance from other law enforcement officers than are stationed in that particular area at that time

Model Limitations & Ethical Conflictions

Our model has a number of limitations. First, it fails to account for buildings or other geographical objects, including runways and rivers, that would hinder the placement of an officer in a given area. Our model is designed to give suggestions as to the general area of officer placement rather than telling the user exactly where officers should be placed. This means that it is still up to the police force to make the call as to the specifics as to where officers should be placed. Our model is not designed to go into specifics because it is impossible to predict crime impeccably.

Another limitation of our model is its curve fitting ability. It uses only linear algorithms to attempt to predict the crime in an area, where in some cases it would be more useful to try other methods of curve fitting. However, these methods of forecasting were general enough to fit a large variety of trends and patterns, and sometimes even no patterns.

Our model also does not place officers where there has been no past crime. This could cause crime to spring up in those areas due to lack of law enforcement. While it is prudent to address these situations, our model only forecasts where crime is most likely to occur.

Our program does not take into account human behavior, demographics, or other aspects that may influence crime; it is based mostly on past crime rate. With so many factors in play, and the unpredictability of society and human nature, it is close to impossible to predict crime in an area with complete certainty.

Mapping crime has many disadvantages on top of its benefits [22]. It is not to be viewed as a perfect solution to Albuquerque's high crime rate but rather a tool to best utilize what Albuquerque has right now until a better solution can be found. A major influencing factor on the high crime levels in Albuquerque is poverty, and our program does not model the widespread poverty that affects Albuquerque's population. Our only goal is to provide a tool for police to use strategically and to good effect against criminals.

With all of the limitations with our model, it is not meant to be blindly adhered to. It is meant to be a useful tool to determine the possibility of forecasting crime and attempting to station police officers to approach crime from the best angle possible in order to minimize cost, unneeded imprisonment, resources, and casualties.

Many people have moral issues with mapping crime. They believe that crime mapping would lead to unfair targeting of certain populations and often cite human rights issues [23,24,25,26,27, 28]. When arguing against crime mapping, many also cite mass victimization and discrimination against certain populations like the events that occured during the war on drugs [29,30,31]. Our team understands that this could be an issue, and we can't determine the best way to fix this. We believe that our tool is to be used as a suggestion for the police force rather than something meant to unfairly imprison people or cause unneeded strife among the impoverished.

Conclusions

Based on the results of our project we have concluded that crime can be mapped and modeled and that police officers can be stationed off of the data to a certain extent. Although our crime map has certain limits and weaknesses, it could still be an effective method for stationing police officers. We have found that crime mapping, when used correctly, can work, so long as its faults are accounted for and the users of this tool don't use it in place of good judgement and experience. We have concluded that our tool can be effective when used correctly, but can also be dangerous when interpreted incorrectly.

In summary, the crime rates of Albuquerque are high, which leads to minimal development, economic insecurity, and tarnished reputation. Our solution to reducing rates is to make better use of the officers and resources currently in Albuquerque. Our model can (to a certain degree) accurately model crime and (to a certain degree) effectively place police officers in the area where they would be of most use, which would discourage and catch crime in those areas, which could effectively reduce the amount of crime in Albuquerque with the current or fewer resources and law enforcement officers.

Future Development

There are many factors that seem to play a role in crime rate in addition to poverty and previous crime. In the future of this project, we would include many of the factors that can influence crime into our model in order to more accurately predict where crime may occur. In addition, it would be important to take geography into account when placing officers. We would also ensure that places with no crime currently detected do not get skipped over, and that they have some attention.

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Acknowledgements

We would like to thank the Albuquerque Chief of Police for responding to our questions and giving us much needed information regarding the time and location of crimes committed in the Albuquerque area.

We would like to thank the Real Time Crime Center in Albuquerque for giving us the information that we needed to complete this project.

We would like to thank Lazo Maximo for evaluating our interim report and providing valuable feedback. Thank you for taking time out of your day to aid our efforts.

Thank you to Jay Garcia for being our mentor and advisor. Your dedication to us has been endearing, and we are truly grateful.

Thank you to Tori Finlay, Azza Ezzat, and Sharon Sessions for reading our report and helping us to perfect it.

Thank you to the Supercomputing Challenge organizers and volunteers for all your hard work! Without you, this challenge would not be possible.