



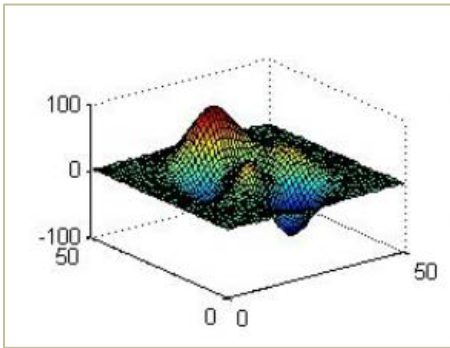
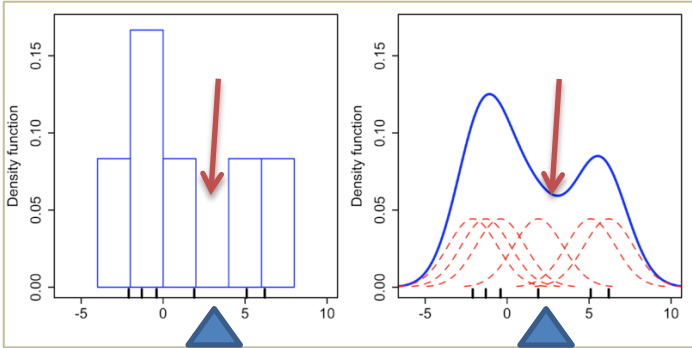
Forensic Geography
 Lab: Hot Spot Analysis 2
 Kernel Density Analysis
 (adapted from ESRI)

Background

Hot spot analysis is a commonly used tool in crime analysis and the goal of this technique is to identify clusters of criminal activity on a map. This would allow authorities to better allocate resources and protect potential victims of crime.

After you have already determined that clustering is actually occurring through Nearest Neighbor Analysis, (or perhaps after you've skipped that step) you may want to map the clusters in a visually pleasing, easy-to-understand format. Kernel Density Smoothing is a technique that does that.

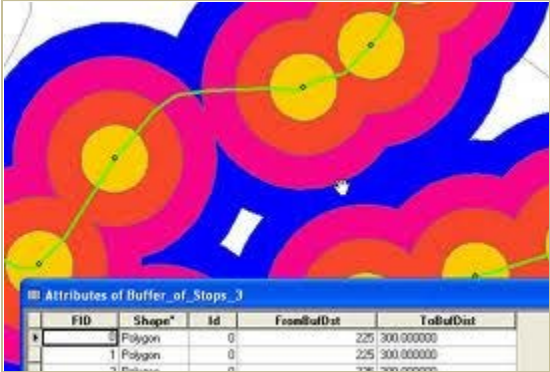
You should know a bit about how this tool works. Consider the two dimensional histogram below on the left. It represents the frequency of some event (like crimes on blocks of a street) on the Y axis (vertical) and the location of the events (like crimes on blocks of a street) on the horizontal X axis. At space 3-4, you see NO events, indicated by the red arrow. Though there may be no crime reported at that location, people at that address are still affected by crime at adjacent locations. How to represent that reality? Kernel Density smoothing “smooths out” the histogram, by assuming that an event doesn’t affect just a single point along the X axis, but rather it affects its “neighborhood” along the X axis....and in the process portrays what is likely the “neighborhood effect”. Perhaps just “nobody got caught” at that blank address or on that block....but that doesn’t mean the surrounding blocks or addresses are not affecting the persons at the address/block without crime data.



Three dimensional representation of Kernel Map

Kernel Smoothing can be done on a map of points as well, but rather than using bell curves (right to left) along a point on an axis, the “bell curve” spreads out in a circular shape, or even in three dimensions (see above) from a point. Think of a large series of buffers circles around each point. Each ring of the buffer carries with it a score that descends with distance from the point. The further you are from a crime, the lower the score. If there are multiple crimes at a single point, or close by...the score will be higher.

In the image of buffer rings to the right, the Kernel Density function would essentially sum the value of buffers that were near the point (e.g., yellow= score = 5; blue = score = 1) Any locations that had two yellow buffers overlapping each other would get a score of 10. Where a blue and a yellow buffer overlap, that region would get a score of 6. Where two blue buffer zones overlap, that region would get a score of 2.



Skills

You will demonstrate an understanding of the principles behind Kernel Density Smoothing as well as how to create Kernel Density Maps in ArcMap10.

1. Demonstrate an understanding of the process by which ArcMap creates a Kernel Density surface map.
2. Demonstrate the ability to create a raster based Kernel Density HotSpot Map
3. Create a polygon shape map from the raster map.

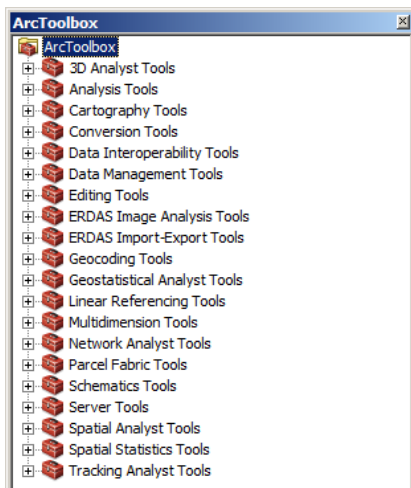
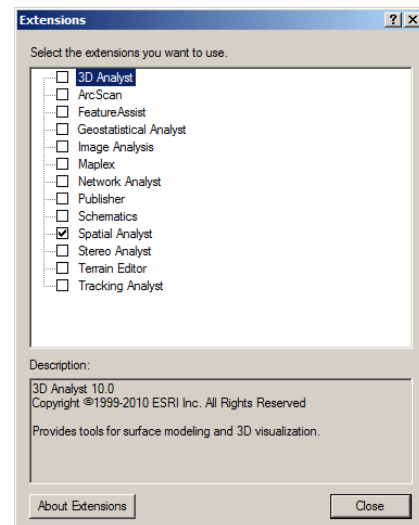
Your Task: Create Map of Crime Density in Pittsburgh with the Kernel Density Tool.

Step 1: Open the HotSpot 2 Lab map document

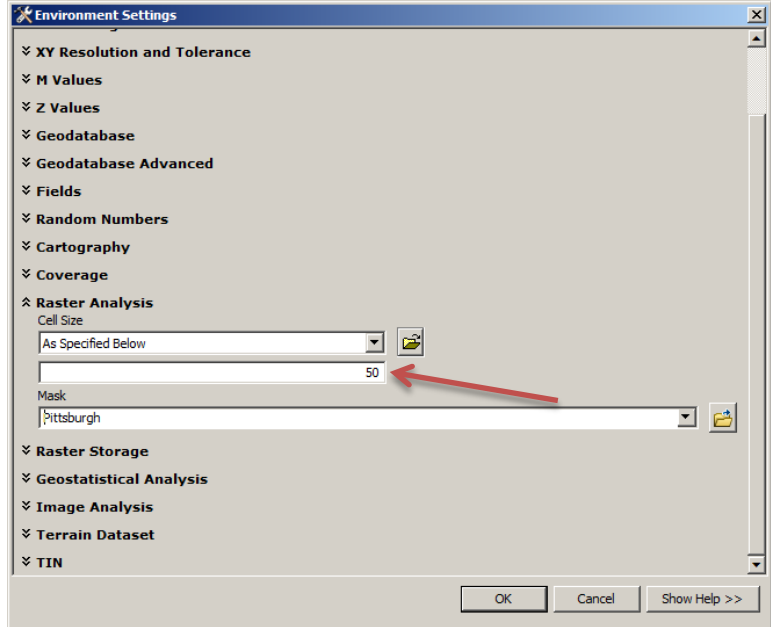
1. In the Forensic course folder on the Y: drive, open the ArcMap document (project file) Pittsburgh_KDS.mxd
it's inside the ESRI folder (Y:/courses/courses_sgraves/Forensic/KDS/Pittsburgh_KDS.mxd)
2. Save a copy of it to your Z drive (or elsewhere if you must be that way).
3. Note that this map shows 911 drug calls for summer 2008 (June through August) in Pittsburgh, Pennsylvania. You can see what appears to be quite a bit of spatial clustering in several parts of the city. You can also see the city borders, police beats and census tracts, plus the three rivers.

Step 2: Turn the Spatial Analyst Extension On.

1. Make sure the correct tools are available to you click on the Menu bar and chose Customize > Extensions. Select the Spatial Analyst check box to turn the extension on. Click Close. There are no apparent changes, but now you can use Spatial Analyst.
2. If necessary, click ArcToolbox on the Standard toolbar to open the ArcToolbox window. In the ArcToolbox window, **right-click** the ArcToolbox icon and select Environments. Lengthen the Environment Settings window so you can see all the possible settings.
3. Click Workspace and make selections as shown in the figure below (if you want to keep ALL your work in the same directory on the Z drive. You may have to create a new folder called "Scratch".)
4. In the Processing Extent options, select from the drop down menu, in the Extent window "Same as layer Pittsburg". This will create a boundary box in which the analysis and any new layers you create will be constrained.



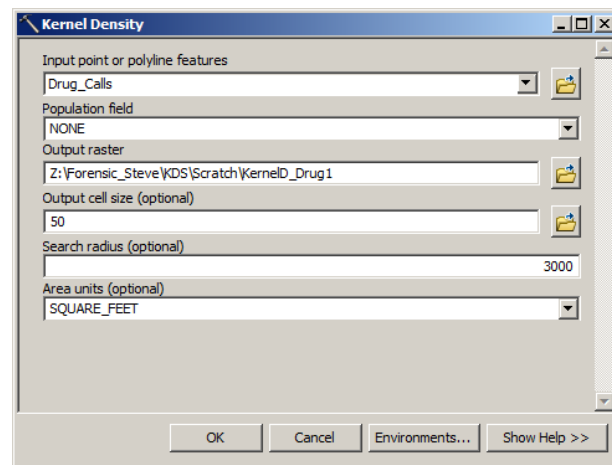
- Next, Click "Processing Extent" to close the panel. Then click Raster Analysis to expand that panel and enter selections as shown in the figure below. When finished, close the Raster Analysis panel. We are changing the raster analysis parameters because although the default setting of 1 foot cell size looks great, it may slow our computers down too much. Setting the cell size to 50 feet is adequate (our map is in feet). Raster maps are all rectangular in shape by necessity. Specifying a mask limits the display of such a map to a jurisdiction boundary, such as Pittsburgh and then ArcMap assigns all raster cells outside the mask (Pittsburg) to No Color, thus making those portions of the map invisible/transparent.
- Click OK to save the settings.



Step 3 Apply Kernel Density Smoothing

The critical parameter to vary in the kernel density method is the search radius. The search radius includes points within that distance of a grid cell used to estimate the expected, or "smoothed," drug calls per square foot. The search radius will be relatively small because the expert cluster ellipses are small-around 2,000 ft along the long axis and 1,000 ft on the short axis. So, try 3,000, 1,000, and 500ft for the search radius and see if one of these radii generates peak areas that match a desired ellipse pattern.

- In ArcToolbox, expand the Spatial Analyst toolbox and then the Density toolset. Then double-click the Kernel Density tool.
- Enter selections as shown in the figure → REMEMBER, you might not be able to use the drop down option for Input Point...so to remind you the Drug_Calls.shp file is in Y:\courses_sgraves\Forensic\NearestNeighbor
- Click OK. Give the software time to produce a map. This is the smoothest of the three surfaces you'll create, because it has the largest radius. In fact, it looks too smooth, as if it could use more peaks and valleys.



Step 4: Symbolize Density Surface

The following steps help you avoid a potential problem in symbolizing the raster map. You need to execute this step just once for a given map document.

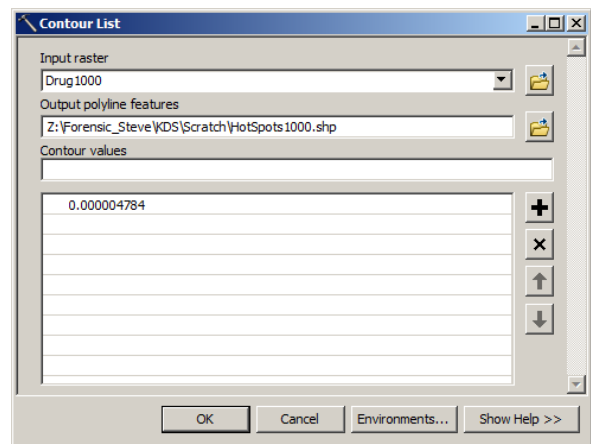
- From the Menu bar, click Customize > ArcMap Options. Click the Raster tab and then the Raster Catalog tab. Type 1000000 (one million) for "Maximum number of rasters for color matching." Then click OK.
- Double-click your new raster layer in the table of contents and click the Symbology tab.
- Click Classify.
- For Classification Method, select Standard Deviation, and for Classes, select 1/3 Std Dev. Click OK.

14. Select the color ramp that ranges from red to yellow to blue. Click the Symbol heading above the resulting color chips in the Symbology panel and select Flip Colors so that low densities are blue and high densities are red.
15. Click OK.
16. Turn the DrugsCollected layer on and off for comparison with the kernel density and supplied hot spots.
17. Try zooming in on hot spots. This level of smoothing, with a search radius equal to 3,000 ft search radius 3,000 ft, does a nice job of capturing large hot spots in the red-colored raster cells. It might serve well as a map for the public-say, with the use of neighborhoods instead of police sectors. You'll need smaller hot spots, however, to direct police patrols. Drug dealing and gang turfs are more on the order of several blocks, which is smaller than these areas.
18. Run kernel density smoothing two more times, once with a search radius of 1000 ft and give it a name like "Drugs 1000" and then do it again with a search radius of 500 ft, and name it Drugs500.
19. Symbolize these layers as you did the 3000 ft. radius map.
20. Save the new raster layers and begin examining them...
21. Save your map document.

Step 5: Create Contour Polygons Defining a Drug Hot Spot

The blue to red color ramp you have been using has hot colors that correspond to the threshold levels needed to define hot spots. Part of the reason this choice of color ramps works is because you used standard deviations for break points in the color ramp, and the high standard deviations pertain to the very high values of the distribution. Next, you'll learn how to convert the boundaries of the hot spot cells of the 1,000 ft radius map into vector contour lines stored as polygons. The polygon format makes the results easier to use and display.

22. In the ArcToolbox window, expand the Spatial Analyst toolbox and then the Surface toolset. Then doubleclick the Contour List tool.
23. Enter selections as shown in the figure at right. Hint: Type the value 0.000004784 in the text box directly under the Contour Values label, and then press the Add (+) button to get the value entered as shown in the figure. The contour value of 0.000004784 corresponds to the start of the second-highest range (reddish orange color chip) in the 1,000 ft search radius density map. So, the resulting contours will enclose hot spots that are reddish orange and red on the color ramp.
24. Click OK.
25. Turn all density maps off and turn HotSpots1000 on.
26. Symbolize the resulting HotSpot1000 layer with an outline of width 2. The result is a simple representation of drug hot spots that can be used for directing patrols.
27. Turn on the "SuppliedHotSpots" layer. Notice that the contours from kernel density smoothing fit the supplied expert hot spots reasonably well. Also, some hot spots cross the boundaries of more than one police sector, suggesting that corresponding patrol units should coordinate patrols in the affected areas.
28. Finally, kernel density smoothing found more hot spots than there were in the set of expert hot spots, but the latter dataset was intended only as a representative sample for training kernel density smoothing and not as the definitive set of hot spots.
29. Save your map document.



Your Assignment

1. Grab a screen capture of your last map. Make sure this screen capture displays the Drug Calls points, the 1000 feet raster (Kernel Density Map) and the HotSpots1000 layers (the map you made last). You can turn off the "SuppliedHotSpots" if you'd like.
2. Paste that into a Word document.
3. Write a paragraph (or two) in which you describe the contents of the map. Make sure you offer an explanation of the logic driving Kernel Density mapping. Your instructor must be certain that you understand how kernel density mapping works. See below if you need some additional information.

Additional Background Information (from Gorr and Kurland, 2011)

Hot Spot Analysis Concepts

Several studies have shown that very small parts of urban areas, hot spots, generate a very large number of crimes (for example, see Weisburd et al. 2004). Hot spots tend to persist, so identified hot spots make good targets for law enforcement and crime prevention. The objective of hot spot analysis is to automatically identify and estimate the boundaries of crime hot spots-spatial clusters of crime incidents for a certain period of time-to provide a "snapshot" of crime. Hot spots are also dynamic-they emerge, persist, decline, and re-emerge. The field officers' pin map in chapter 3 and corresponding animations in chapter 6 help identify such dynamic behavior because they include crime map layers from different time frames, providing a time context. You can see newer crimes in the context of recent but older crimes. Spatial clustering and surface estimation are two approaches to automatically identifying hot spots. Spatial clustering involves searching for crime incidents that occur unusually close to each other. Surface estimation assumes there is an expected or average crime density (crimes per unit area) distributed over space that is smooth and continuous. The peaks of this surface define the hot spots. In this chapter, you learn how to use both clustering and smoothing techniques.

Surface estimation using kernel density smoothing

Surface elevation is commonly used with rasters to illustrate crime density through surface estimation. A raster map is similar to a photograph and consists of a rectangular matrix of very small square grid cells, each with its own solid color. Raster maps can be used to portray surfaces that can then be used to depict varying levels of crime. You will create raster maps in this chapter that represent crime density-the expected or mean level of crime per unit area-through the use of surface elevation. The higher the expected crime count per unit area, the higher the surface peak. But rather than representing mountain peaks, the elevation in your raster maps will represent crime density peaks, or crime hot spots.

"What is raster data?"

Kernel density smoothing is a leading method of surface estimation. "Kernel" is a mathematical term for a kind of function that can be used for averaging. Kernel density smoothing assigns a bell-shaped surface (the kernel) over every crime location, with the highest point of the bell directly over the crime location. Then at each point on the map, the kernel density smoothing method simply sums up all the bell surfaces overhead. Nearby crimes contribute a lot to the sum while distant crimes add only a small amount. The more crimes clustered near each other, the higher the surface at that point. The result, the kernel density surface, changes smoothly over space. For example, in the figure, the clustered drug calls for service result in crime density peaks, shown in red.

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This map shows drug calls for service for a three-month period, gold standard hot spots, and a kernel density smoothing surface.

Kernel Density Smoothing

Hot spot analysis with raster maps amounts to estimating the crime surface over a jurisdiction, and then selecting a threshold elevation to yield a decision on what constitutes a hot spot. Any area (collection of raster cells) that is at or above the threshold is then considered a crime hot spot. The threshold in the figure map is the minimum crime density that corresponds to the boundary of the red areas. The red areas have crime density at the threshold or higher.

Calibrating kernel density smoothing for hot spots

The critical parameter for calibrating (or tuning) kernel density smoothing is the search radius (or radius of the bell surface placed over each crime). A relatively long radius results in "long rolling hills" for the surface,

whereas a short radius results in sharp peaks. Of course, the search radius you need depends on the nature of the hot spots you want to identify.

Implementing hot spot methodology in practice, however, including kernel density smoothing, has led to a great deal of confusion, largely because there has been no "gold standard" approach to designating true hot spots for use in calibrating hot spot estimation methods. Some crime analysts use "rules of thumb" based on expert opinion for kernel density calibration, but there is no way to determine how such rules perform without having a target in place.

The approach used in this chapter to arrive at these gold standards, or assumed true hot spots, is to have crime analysts study crime pin maps and use their expert judgment to manually draw boundaries around the areas they perceive as hot spots. All that is needed is a good sample of expert hot spots; you do not have to exhaustively identify all hot spots in a dataset. Three gold standard hot spots are shown in the kernel density smoothing figure.

In kernel density smoothing, a search radius must be found that generates a crime density surface in which the peaks approximate the gold standard hot spot boundaries. This is not difficult, as you will see in the following exercises. The red areas of the kernel density smoothing surface in the kernel density smoothing figure do a reasonable job of approximating the gold standards identified there. In effect, this approach automates crime analysts' expert judgment by calibrating hot spot methods to replicate crime analysts' expertise as much as possible. The result is a hot spot method that saves time, is comprehensive, and provides consistent hot spots for police work. See "Empirical Calibration of Time Series Monitoring Methods Using Receiver Operating Characteristic Curves" (Cohen, Garman, and Gorr 2009) for an in depth approach to calibrating methods for detecting the emergence of crime hot spots.

Conducting Hot Spot Modeling

The workflow in the following exercises starts with testing for the existence of spatial clusters, moves on to kernel density estimation of hot spots calibrated by using expert judgment, and finishes with confirmation of the kernel density results by using the Getis-Ord G_i^* hot spot analysis. You'll be using the tools that ArcMap provides in ArcToolbox, which simplifies the work. All you have to do is open a tool's parameter input form, select the inputs, and then run the tool to get the outputs.