Penn Student Data Question - Kernel Density Estimation Analysis of Gun Crime in Philadelphia

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Purpose

The purpose of this memo is to aid in addressing Nissim Lebovits question of finding a suitable interpolation method to estimate the density of firearm-related incidents across Philadelphia. This memo will explore the differences between fixed and adaptive kernel density estimations interpolation methods using firearm related incidents in Philadelphia from 2015-2021. These methods will be examined individually and compared to assess performance.

Data and Methods

The data for this analysis is from OpenDataPhilly, via the Philadelphia Police Department and the city of Philadelphia. The Philadelphia Police Department supplied data on firearm-related criminal incidents between 2015-2021, and the city of Philadelphia supplied the city limits boundary. The police data contains several fields, but the most pertinent were the incident date, uniform crime report (UCR) code, the uniform crime report text general code, and the latitude and longitude. Next, the city boundary file is a shapefile that shows a single polygon of the city limits of Philadelphia.

Next, the methods employed in this analysis are a Fixed Bandwidth Kernel Density Estimation and Adaptive bandwidth Kernel Density Estimation. These interpolation methods

have been utilized in criminal justice, public health, environmental science, and more disciplines. Moreover, the reason for such broad usage of this method is that it is beneficial for estimating phenomena at specified search radii, which helps create smoothed continuous surfaces across study areas that are not constrained to administrative boundaries (e.g., census tracts, block groups, or zip codes) and, in turn, can provide a greater understanding of phenomenon patterns and variations within a study area with respect to space and time.

Standard kernel density operates as follows: (1) generation of a grid over a point distribution; a specified search radius that moves over the points in three-dimensional space; (3) the final calculation of grid cells, which sums all estimates for each cell location (Ratcliff & Chaney, 2005). As previously mentioned, the method is excellent for understanding patterns of particular phenomena. However, depending upon the orientation of the point data, it can result in over smoothing of specific areas. To alleviate this problem of over-smoothing, an adaptive bandwidth can be utilized. This adaptive version of Kernel Density Estimation uses a variable bandwidth to compute an adaptive estimate of the point pattern at cell locations (Davies & Baddeley, 2018).

Results

Figure 1 displays a fixed-bandwidth kernel density estimation of firearm-related incidents in Philadelphia for the study period. Firearm related criminal incidents densities are the greatest in North, West, and South Philadelphia. Also, they appear to radiate out and become less dense the further away from those three main hot spot regions. Regions with low densities of firearm related criminal incidents are in the Northwest and Northeast.

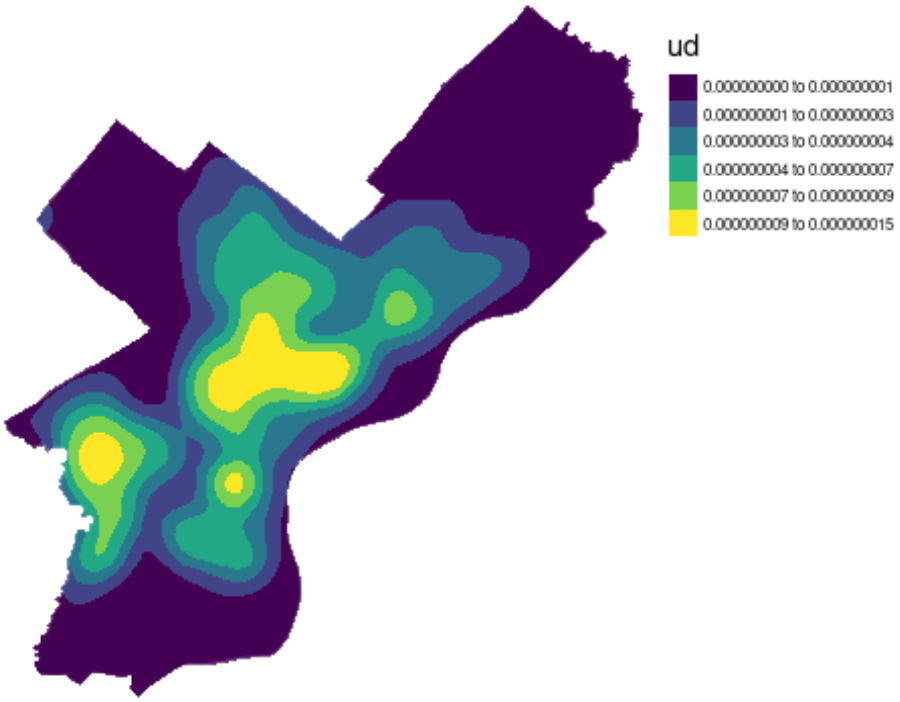

Figure 1: Fixed-bandwidth Kernel Density Analysis of Firearm Related Incidents in Philadelphia.

Figure 2 shows the adaptive kernel density estimation of firearm-related incidents in Philadelphia from 2015-2021. The patterns shown are similar to the areas with the greatest densities in *figure 1*. However, there is a greater level of variation within those areas with high and low firearm related crime densities within the same area. Moreover, there appears to be pockets of firearm related criminal incidents in Lower Northeast, while low density areas are scattered throughout Upper Northwest and Northeast. Comparing both methods, it is evident that the fixed-bandwidth results in over-smoothing of the data within the study region and in turn reduces the variation of firearm patterns in the city. Contrarily, the adaptive-bandwidth displays the lost variation from the fixed-bandwidth method.

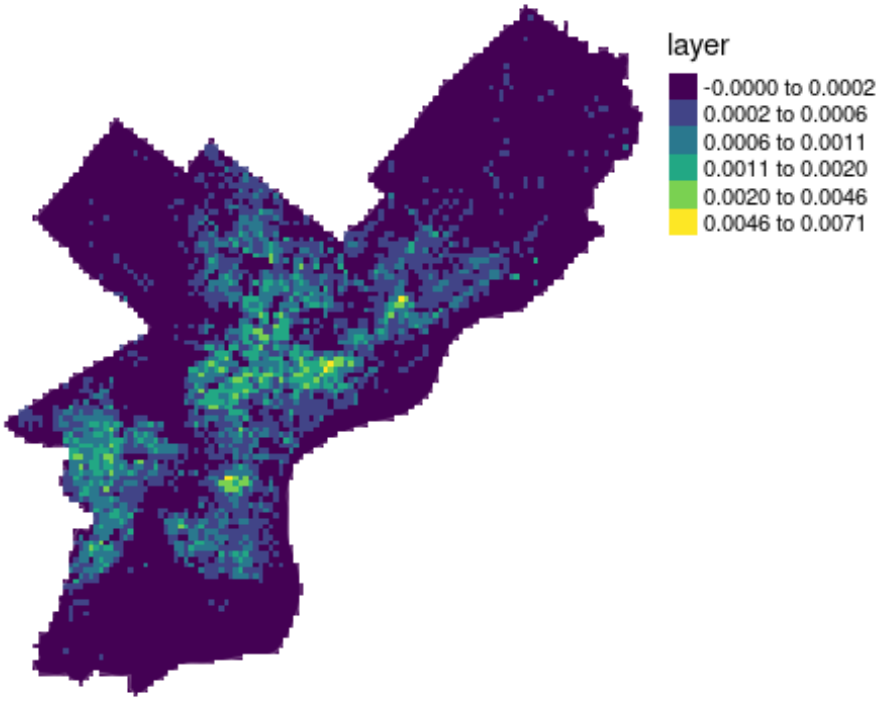

Figure 2: Adaptive-bandwidth Kernel Density Analysis of Firearm Related Incidents in Philadelphia.

Conclusion

Overall, the two kernel density estimation methods performed well in identifying areas with high concentrations of firearm-related criminal incidents. However, it appears that the adaptive kernel density estimation method performed better in identifying nuance of the densities in the study area.

Caveats

Police criminal incidents data are offset from the true location, so this may affect the concentration levels of firearm related criminal incidents in certain regions of Philadelphia.

Works Cited

Chainey, S., & Ratcliffe, J. (2005). *Gis and crime mapping* (1st ed.). Wiley. https://doi.org/10.1002/9781118685181

Davies, T. M., & Baddeley, A. (2018). Fast computation of spatially adaptive kernel estimates. *Statistics and Computing*, *28*(4), 937–956. https://doi.org/10.1007/s11222-017-9772-4