ImprovingsocialharmindiceswithamodulatedHawkesprocess

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ABSTRACT

Communitiesareaffectedadverselybyarangeofsocialharmevents,suchascrime,trafficcrashes,medicalemergencies,anddruguse. Thepolice,fire,healthandsocialservicedepartmentsaretaskedwithmitigatingsuchsocialharmthroughvarioustypeofinterventions. Whilevariousdifferentsocialharmindiceshavebeenproposedforallocatingresourcesstopartiallyfixedhotspots,theriskofsocialharm eventsisdynamic,andenewalgorithmsandsystemsoftencapecapableofquicklyidentifyingrisksandtriggeringappropriatepublic

safetyresponsesareneeded.WeproposeanovelmodulatedHawkesprocessforthispurposethatoffersflexibleapproachesto(i)the

incorporationofspatialcovariatesandleadingindicatorstovanagementreductioninthecaseofrarereventcategories,(ii)thecapture

dynamichotspotformationthroughself-excitation.Wepresentanefficientl1-penalizedEMalgorithmforestimatingthemodelthat

performsfeatureselectionforthespatialcovariatesofeachincidenttypesimultaneously.Weprovidesimulationresultsondatafrom

theIndianapolisMetropolitanPoliceDepartmentinordertoillustratetheadvantagesofthemodulatedHawkesprocessmodelofsocial

harmovervariousrecentlyintroducedsocialharmindicesandpropertycrimeHawkesprocesses.


1. Introduction

Crimeishighlyconcentratedinurbancommunities,and

hotspotor“predictive”policingeffortsaimtoapplylim-

itedresourcestohighintensitygeographicareasandtime

intervals inorder to disruptcrimeopportunities,leading
toaggregatecrimeratereductions(Braga&Bond,2008;

Mohleretal.,2015;Ratcliffe,Taniguchi,Groff,&Wood,

2011;Weisburdetal.,2006).Anumberofdifferentalgol-

rithmicsmodelshavebeenproposedforestimatingcrime

hotspotrisk,includingmultivariatemodels(Kennedy,

Caplan,&Piza,2011;Liu&Brown,2003;Wang,Brown,&

Gerber,2012),kerneldensityestimation(Bowers,Johnson,

&Pease,2004;Chainey,Tompson,&Uhlig,2008;Fielding

&Jones,2012;Johnson,2007;Johnson,Bowers,Birks,&

Pease,2009)andspatio-temporalpointprocesses(Mohler,

2014;Mohler,Short,Brantingham,Schoenberg,&Tita,

2011).Pointprocessesanddensityestimationhavethead-

vantageofcapturingnear-repeateffectsonlyandonly

requireeventdataasinputs,whereasmultivariatemodels

achiev_variance_reductionthroughtheintroductionof

spatialcovariates(thoughthevariancecanbeincreasedif

irrelevantcovariatesareincluded).Mohleretal.(2015)

cottiedfieldtrialsofpredictivepolicingusingaprop-

ertycrimeHawkesprocess,wherepatrolsdirectedthrough

theHawkesprocessledtostatisticallysignificantcrimerate

reductionscomparedtoanalyst-directedpatrols.

However,thepolicealsofillotherrollsinthe

communitybeyondcrimeresponseandprevention,including

trafficenforcement,emergencymedicalservices(EMS)

response,andmoregenerallydealingwitheventsr related
tosocialharm(Ratcliffe,2015).Despitethesemultiplyand

disparate dailychallenges, theexisting hotspot and pre-

dictpolicing algorithms and intervention strategies focus

onindividualsorgroupsofrelatedsub-categoriesofsocial

harmevents.Scholarshaverecentlycalledforthenext

evolutionofhotspotpolicingtomovebeyondcrime

countsinspaceandtimetothemoreexpansiveandhierarchi-

capproachofpolicing“socialharm”(Ratcliffe,2015;Sher-

man,Neyroud,&Neyroud,2016;Weinborn,Ariel,Sher-

man,&O’Dwyer,2017).A recentapproachtoquantifying

theimpactofcrimesonsocietyhasbeenthe development of

crimeharmindices(Curtis-Ham&Walton,2017;Sherman
et al., 2016) that attempt to weight crime offenses based on sentencing guidelines, as opposed to the simpler count measures of crime occurrences. In this context, harm is operationalized as the impact upon society, depending on the qualitatively different levels of severity across incidents of crime. This approach to quantifying crime has implications for the development of more effective police interventions for reducing harm, as opposed to reducing crime counts. With this end-goal in mind, Ratcliffe (2015) extends the idea of a crime harm index to a social harm index that includes incidents to which police must respond that fall outside the traditional definition of crime but still inflict harm on society, such as vehicle crashes. The current study takes the notion of social harm a step further to include additional incidents within the police purview that affect society. Here, harm is operationalized beyond the impact of crime on society to be more inclusive of the nature of police work. Put simply, a focus on social harm builds on hotspots policing by applying similar methodological approaches, but broadens the list of harm incidents to reflect day-to-day policing demands (e.g., crime, medical emergencies, vehicle crashes, etc.) more accurately, while weighting these various incidents to reflect the degree of severity of the harm each may inflict upon society.

The preliminary findings in social harm research suggest that the inclusion, and weighting, of various harm incidents holds substantive promise for police practice and intervention. To date, the most common approach to weighting social harms has been to map sentencing data to specific crime offenses. This method has taken the form of both actual sentencing outcomes (Babyak, Alavi, Collins, Halladay, & Tapper, 2009; Bangs, 2016; Curtis-Ham & Walton, 2017) and prescriptive sentencing guidelines, often referred to as gravity or severity scales (Ratcliffe, 2015; Sherman et al., 2016; Weinborn et al., 2017), and makes use of suggested sentencing lengths to rank the “harm” of a given offense. For example, criminal homicide may have a sentencing guideline of 24 years in prison, while armed robbery may elicit a 12-year sentence, and residential burglary a 6-year sentence. In such a weighting scenario, criminal homicide would be twice as severe or harmful as armed robbery and four times as harmful as residential burglary. Weighting by sentencing guidelines can take many forms, and the discussion presented here is limited to the importance of weighting crimes and other incidents by their severity. Indeed, “neither criminology nor the adjacent social sciences have made a serious effort to systematically identify, evaluate or compare the harms associated with different crimes” (Greenfield & Paoli, 2013) and “focusing merely on counts, rather than on the severity or harm of crime, is somewhat crude and imprecise” (Weinborn et al., 2017). Sherman et al. (2016) provide a robust discussion of varying weighting procedures using sentencing guidelines.

Studies employing this approach have concluded that social harm varies across police patrol districts (Ratcliffe, 2015) and that a small proportion of crime victims are exposed to greater levels of social harm (Dudfield, Angel, Sherman, & Torrence, 2017). Most closely related to the current study, Weinborn et al. (2017) employed the Cambridge Harm Index (CHI) of Sherman et al. (2016) wherein crimes are weighted by the number of days in prison for a given offense, as outlined in the Home Office Sentencing Guidelines, to examine the spatio-temporal concentration of crime counts versus CHI social harm. Their results indicated social harm to be three times as concentrated as crime counts alone across 15 councils in England and Wales over a 12-month period. Interestingly, and critically in pointing out the need for scholars to consider a variety of social harms beyond traditional hotspot policing strategies, the authors observed that only 25% of their crime count hotspots overlapped with their social harm locations, or “harmspots”. Thus, while it can be insightful to conduct spatiotemporal analyses of crime counts alone in order to focus police strategies, it seems prudent to account for the severity of the harm that crime may cause, as crimes are not all created equal, and the spatiotemporal variation of more harmful incidents may differ from that of less harmful events. Moreover, given that harmspots exhibit different spatiotemporal patterns from hotspots, they may also have different corollary relationships with community structure from hotspots; hence one focus of the present study.

The present study contributes further to the social harm policing literature through the inclusion of multiple harm types that are yet to be examined in a single study. The present study includes a range of Part 1 (the most serious crimes that occur regularly across all jurisdictions and are likely to be reported to the police) and Part 2 (other crimes) criminal offenses, as well as vehicle crashes and drug overdoses — the latter of which is currently regarded as one of the most concerning social harms, as drug overdose deaths across the United States have more than quadrupled since 1999 (Rudd, Aleshire, Zibbell, & Gladden, 2016). Part 1 and Part 2 criminal offenses are defined by the Federal Bureau of Investigation (2016) as a tiered classification system for the Uniform Crime Reporting and National Incident Based Reporting System. Furthermore, unlike static social harm indices that are estimated over a fixed historical window of observation, our methodology produces a dynamic harm index that incorporates new event data daily to account for spatiotemporal fluctuations in the social harm risk.

This study introduces a modulated Hawkes process for modeling dynamic social harm hotspots. The model combines several advantageous aspects of existing multivariate regression and point process models. In particular, the model consists of a background modulated Poisson process that links spatial covariates (census variables, average crime rate, etc.) to the risk of each social harm event category. Our estimation procedure also includes automatic variable selection in order to prevent over-fitting and determine important covariates for model explanation. Secondly, the point process approach allows for the incorporation of the self-excitation that is present in some event categories. Because the output of the modulated Hawkes process is a conditional intensity for each event type, a dynamic social harm index can be defined easily by calculating the expected cost of a given spatial region and time interval.

The outline of this paper is as follows. Section 2 gives an overview of the data set used in our study and the methods that are used to estimate the average societal cost of each event type. Section 3 provides the mathematical details of the modulated Hawkes process and a 11-penalized...
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