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Establishing Situational Context in Risk Terrains

Keywords: Conjunctive Analysis, Violent Crime, Aggravated Assault, RTM.
Aim: To demonstrate the joint utility of conjunctive analysis and risk terrain modeling.
Excerpts:

- *"Only through the conjunctive analysis data matrix could we clearly see the aggravating and/or mitigating interaction effects of each risk factor on all other risk factors, and combinations thereof."*
- *"Conjunctive analysis seems to be of great value in furthering the meaningful and actionable information that can be derived from a risk terrain model."*

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Background

Risk terrain modeling (RTM) "paints a picture" of the backcloth for crime throughout a jurisdiction. It does this using existing technology, data, and GIS (geographic information system) procedures to combine multiple crime factors to produce a composite map showing the presence or absence of multiple risk factors at micro places. RTM has been used to empirically test ideas about emerging conditions leading to crime problems, to deploy police officers to high-risk places, and to help prioritize crime risk factors for intervention efforts. Missing from the current outputs of risk terrain modeling methods and statistical validation tests is an easy way to determine which co-located risk factors account for the greatest relative frequency of crimes compared to all other risk factor combinations. That is, which "situation" (e.g., bars + parks + schools –*or*– bars + parks + fast food restaurants) attracts the most crime events?

It is likely that some interaction effects among certain risk factors in a risk terrain model are stronger that other interactions on the attraction of illegal behavior and crime. Imagine, for instance, we have a 5-factor risk terrain model. Regression modeling (i.e., to test predictive validity) informs analysts about the likelihood of crime occurring at places with every increased risk value. So, places with all 5 risk factors present have the greatest risk, or likelihood, of crime occurring there. But, presumably, places with risk values of "4" should not be treated equal because it is unclear which factor's absence makes the "best" 4-factor model. Places with all 5 risk factors (A, B, C, D, E) present pose the highest risk. But should places with factors A, B, C, D be prioritized over places with factors B, C, D, E or vice versa? Several places can have risk values of "4" but have meaningfully different combinations of risk factors.

Conjunctive analysis was brought to our attention by Dr. Timothy Hart from the University of Nevada, Las Vegas. We think it may advance the practical value of RTM by addressing the issues discussed above. As presented by Miethe, Hart and Regoeczi[1] in 2008, conjunctive analysis investigates the interrelationships among different factors. The output is a data matrix of situational contexts (i.e., every possible combination of risk factor interactions) and the relative frequency of crimes associated with each situation. Following the clear and detailed methods presented in the Miethe et al. article in the *Journal of Quantitative Criminology* (and using

the SPSS, STATA, and SAS syntax that was graciously provided in the article's appendix), we present, here, our first attempt at using conjunctive analysis for RTM.

Study Setting, Data, Methods and Results

The Rutgers Center on Public Security published a research brief in 2012 detailing a statistically valid risk terrain model for aggravated assaults in Kansas City, Missouri (available at http://www.rutgerscps.org/docs/KCPD_RTMAggAssault_Brief.pdf). We used this risk terrain model for the conjunctive analysis because the data was readily available and considered to be reliable. The Kansas City risk terrain model was comprised of 5 risk factors (package liquor stores, grade schools, drug areas/markets, parks, and franchise fast food restaurants). It was representative of the time period from April through October 2010. The risk terrain map was a grid of the entire jurisdiction of Kansas City comprised of 142,221 cells of 250ft x 250ft. (mean block length = 470ft). These cells served as the units of analysis for the conjunctive analysis. "Aggravated assaults" included only substantiated incidents that were recorded and investigated by the Kansas City Police Department from August thru October 2010, and excluded incidents noted as domestic violence (to produce a more reliable measure of "street" crime).

As explained by Miethe, Hart and Regoeczi (2008: p229): *A conjunctive analysis of case configurations begins with an aggregated compilation of all possible combinations of attributes considered simultaneously. The number of possible case configurations depends on the number of independent variables and categories within them. For a conjunctive analysis involving 5 dichotomous independent variables, there are 32 qualitatively distinct case configurations ($2^5 = 32$). …Once the possible case configurations are identified, conjunctive analysis proceeds by aggregating each observation into their respective case configuration and exploring the relative distribution of particular categories of the outcome variable across these configurations.*

For the following conjunctive analysis, the spatial influence of each risk factor in the Kansas City risk terrain model was binary coded in terms of the presence (1) or absence (0) of highest risk at each micro place (i.e., grid cell). As explained by Miethe et al., when displayed in a table of i rows and j columns, each row represents a particular case configuration. The row entries also include the number of observations in the case configurations (N_Cases_i) and the proportional distribution of "presence of" the outcome event within this configuration (e.g., # of Agg. Assaults/N_Cases_i). A data matrix for the conjunctive analysis of the 5 risk factors for aggravated assault in Kansas City is shown below in Table 1.

In Table 1, the "Combination" field is what we describe as the *situational context* for crime in a risk terrain. Each "Risk Factor" variable specifies the *presence of high risk* posed by the spatial influence of each respective feature of the Kansas City landscape. "RiskSum" relates to a *composite risk value* (as if produced via an unweighted risk terrain model; range=0-5). "Relative Count" is the *proportional distribution*, or relative frequency, of aggravated assault incidents located at micro places characterized by each respective situational context. "N_Cases" specifies the number of micro places (i.e., cells) in the risk terrain that are characterized by each respective situational context.

According to a negative binomial regression of "risk value" on the "counts of aggravated assaults" in Kansas City (based on the aforementioned risk terrain model), the number of aggravated assaults was two times higher with every increased unit of risk at a 250ft x 250ft place (N=142,221; IRR=2.034; Std. Err.=0.052; z=27.30; p<0.001; 95% Conf. Int.=1.933-2.141; Pseudo R2=0.125). The conjunctive analysis further validates this finding by showing the lowest proportional distribution (.00052778) of aggravated assaults to be at places with situational contexts that are absent the spatial influences of any and all risk factors, whereas the highest proportional distribution (.05494506) of aggravated assaults is at places where the spatial influences of all 5 risk factors are present. Table 2 shows the conjunctive analysis data matrix sorted by relative crime counts. Figure 1 presents a bar chart of this data matrix.

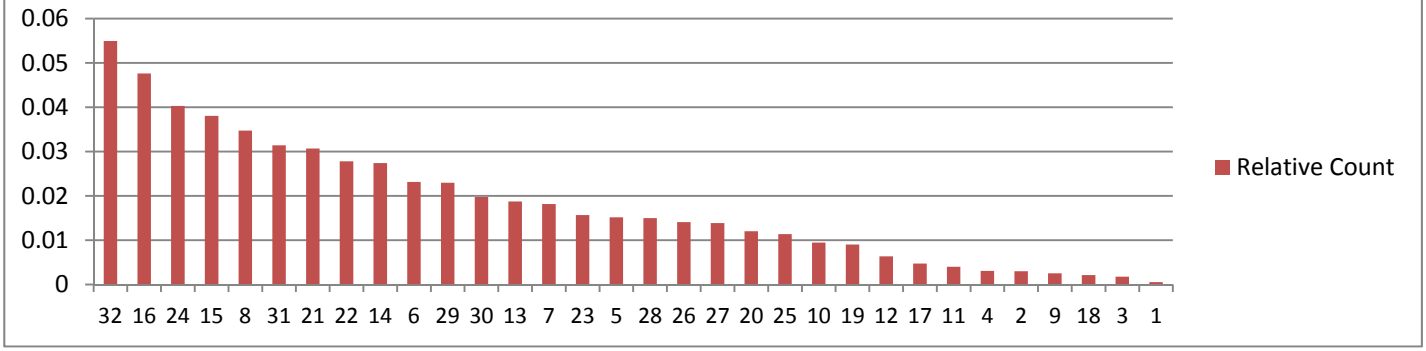
Table 1: Conjunctive Analysis Data Matrix, sorted by combination

	Risk Factor							
Combination	PackLiqr	School	Drug	Parks	FastFood	RiskSum	Relative Count	N_Cases
1	0	0	0	0	0	0	0.00052778	100420
2	0	0	0	0	1	1	0.00297619	1344
3	0	0	0	1	0	1	0.00176505	10198
4	0	0	0	1	1	2	0.00304878	328
5	0	0	1	0	0	1	0.01515944	1913
6	0	0	1	0	1	2	0.02314815	216
7	0	0	1	1	0	2	0.01814059	1323
8	0	0	1	1	1	3	0.03472222	144
9	0	1	0	0	0	1	0.00250459	5989
10	0	1	0	0	1	2	0.00943396	318
11	0	1	0	1	0	2	0.00399564	2753
12	0	1	0	1	1	3	0.00632911	158
13	0	1	1	0	0	2	0.01872075	641
14	0	1	1	0	1	3	0.02739726	73
15	0	1	1	1	0	3	0.03805774	762
16	0	1	1	1	1	4	0.04761905	42
17	1	0	0	0	0	1	0.00470536	4463
18	1	0	0	0	1	2	0.00210526	2375
19	1	0	0	1	0	2	0.00900901	1221
20	1	0	0	1	1	3	0.012	500
21	1	0	1	0	0	2	0.03068862	1336
22	1	0	1	0	1	3	0.02777778	504
23	1	0	1	1	0	3	0.01566952	702
24	1	0	1	1	1	4	0.04029304	273
25	1	1	0	0	0	2	0.01135371	1145
26	1	1	0	0	1	3	0.0140647	711
27	1	1	0	1	0	3	0.01384083	867
28	1	1	0	1	1	4	0.01497006	334
29	1	1	1	0	0	3	0.02296451	479
30	1	1	1	0	1	4	0.01973684	152
31	1	1	1	1	0	4	0.03139013	446
32	1	1	1	1	1	5	0.05494506	91

Table 2: Conjunctive Analysis Data Matrix, sorted by relative (crime) count

	Risk Factor							
Combination	PackLiqr	School	Drug	Parks	FastFood	RiskSum	Relative Count	N_Cases
32	1	1	1	1	1	5	0.05494506	91
16	0	1	1	1	1	4	0.04761905	42
24	1	0	1	1	1	4	0.04029304	273
15	0	1	1	1	0	3	0.03805774	762
8	0	0	1	1	1	3	0.03472222	144
31	1	1	1	1	0	4	0.03139013	446
21	1	0	1	0	0	2	0.03068862	1336
22	1	0	1	0	1	3	0.02777778	504
14	0	1	1	0	1	3	0.02739726	73
6	0	0	1	0	1	2	0.02314815	216
29	1	1	1	0	0	3	0.02296451	479
30	1	1	1	0	1	4	0.01973684	152
13	0	1	1	0	0	2	0.01872075	641
7	0	0	1	1	0	2	0.01814059	1323
23	1	0	1	1	0	3	0.01566952	702
5	0	0	1	0	0	1	0.01515944	1913
28	1	1	0	1	1	4	0.01497006	334
26	1	1	0	0	1	3	0.0140647	711
27	1	1	0	1	0	3	0.01384083	867
20	1	0	0	1	1	3	0.012	500
25	1	1	0	0	0	2	0.01135371	1145
10	0	1	0	0	1	2	0.00943396	318
19	1	0	0	1	0	2	0.00900901	1221
12	0	1	0	1	1	3	0.00632911	158
17	1	0	0	0	0	1	0.00470536	4463
11	0	1	0	1	0	2	0.00399564	2753
4	0	0	0	1	1	2	0.00304878	328
2	0	0	0	0	1	1	0.00297619	1344
9	0	1	0	0	0	1	0.00250459	5989
18	1	0	0	0	1	2	0.00210526	2375
3	0	0	0	1	0	1	0.00176505	10198
1	0	0	0	0	0	0	0.00052778	100420

Figure 1: "Relative Count" (Y axis) for each "Combination" (X axis)



Discussion

We have probably only begun to see the value of conjunctive analysis for risk terrain modeling. And we encourage others to explore the joint utility of these two approaches for crime analysis. Below are just a few of the things we found to be most evident during our initial application of conjunctive analysis to RTM.

First, police deployments should be prioritized at places where the spatial influences of all 5 risk factors are present. But, all "4s" should not receive equal attention. The top five situational contexts for aggravated assaults, which account for a proportional distribution of 0.215 incidents (i.e., located on less than 1% of the area of Kansas City: 91+42+273+762+144=1,312 cells / 142,221 = .0092), include places with interactions of risk factors described by Combinations "32", "16", "24", "15" and "8" (see Table 2). Depending on available resources, police officers should be allocated to "Combination 32" first, then to "Combination 16", "24", "15", and "8", in that order—even though some of these places have only 3 risk factors present. Separate risk terrain maps could be produced to show places where each of these "situational contexts" exists, respectively, and resources could be deployed accordingly.

Second, conjunctive analysis helps to identify possible mitigating factors. For instance, in Table 2, look at "Combination 21" and "Combination 30". "Combination 21" is comprised of only two risk factors and has a "Relative Count" of .030 crimes. "Combination 30" has four risk factors and a "Relative Count" of .019 crimes. The only two factors that each "Combination" has in common are "Package Liquor Stores" and "Drug Areas". Here, the more risk factors present actually results in a smaller relative frequency of crime incidents. So, could it be that the spatial interaction of "Schools" and "Fast Food Restaurants", when co-located with "Package Liquor Stores" and "Drug Areas", mitigates the attraction (i.e., and risk) of aggravated assaults? From this conjunctive analysis, it does appear to be that drug markets located near package liquor stores are environments especially well-suited for aggravated assaults. However, when both package liquor stores and drug markets are also located near schools and fast food restaurants, the risk of aggravated assaults becomes mitigated. In fact, the interaction effect of schools and fast food restaurants together (i.e., Combination 30) seems to have a greater mitigating effect than schools (i.e., Combination 29) or fast food restaurants alone (i.e., Combination 22).

Third, and to harp on the above point a bit longer, we know that schools are a statistically valid risk factor for aggravated assaults in Kansas City, which is why "schools" was included in the risk terrain model. From the conjunctive analysis we realized more specifically that while schools are "bad" in terms of increasing the place-based risk of aggravated assaults, schools near drug areas are "bad-er". Actually, it seems that when "Drugs" interacts with any other factor, it always aggravates the risk posed by the other factor (and increases its "Relative Count". Other factors, however, do not have a similar interaction effect.

Only through the conjunctive analysis data matrix could we clearly see the aggravating and/or mitigating interaction effects of each risk factor on all other risk factors, and combinations thereof. Conjunctive analysis seems to be of great value in furthering the meaningful and actionable information that can be derived from a risk terrain model. We encourage others to give it a try and then share their own insights. Instructions for producing risk terrain models and maps can be found at www.rutgerscps.org. The article by Miethe et al. (https://www.ncjrs.gov/App/publications/Abstract.aspx?id=244515) is a great resource to start learning about conjunctive analysis.

[1] Miethe, T. D., Hart, T. C., & Regoeczi, W. C. (2008). The conjunctive analysis of case configurations: An exploratory method for discrete multivariate analyses of crime data. *Journal of Quantitative Criminology, 24*: 227-241.