The Mathematics of Geographic Profiling

Dr. Mike O'Leary

Towson University

Supported by the NIJ through grant 2005–IJ–CX–K036 and 2007–DE–BX–K005

Project Participants

- Towson University Applied Mathematics Laboratory
  - Undergraduate research projects in applied mathematics.
  - Founded in 1980
- National Institute of Justice
- Special thanks to Stanley Erickson (NIJ), Ron Wilson (NIJ) and Andrew Engel (SAS)

Collaborators

- Dr. Coy L. May (Towson University) (2005-2006, 2006-2007)
- 2005-2006 Students:
  - Paul Corbitt
  - Brooke Belcher
  - Brandie Biddy
  - Gregory Emerson
  - Laurel Mount
  - Ruozhen Yao
  - Melissa Zimmerman
- 2006-2007 Students:
  - Chris Castillo
  - Adam Fojtik
  - Jonathan Vanderkolk
  - Grant Warble
- 2007-2008 Students:
  - Lauren Amrhine
  - Colleen Carrion
  - Chris Castillo
  - Yu Fu
  - Natasha Gikunju
  - Kristopher Seets

Geographic Profiling

- **The Question:**

  Given a series of linked crimes committed by the same offender, can we make predictions about the anchor point of the offender?

- The anchor point can be a place of residence, a place of work, or some other commonly visited location.

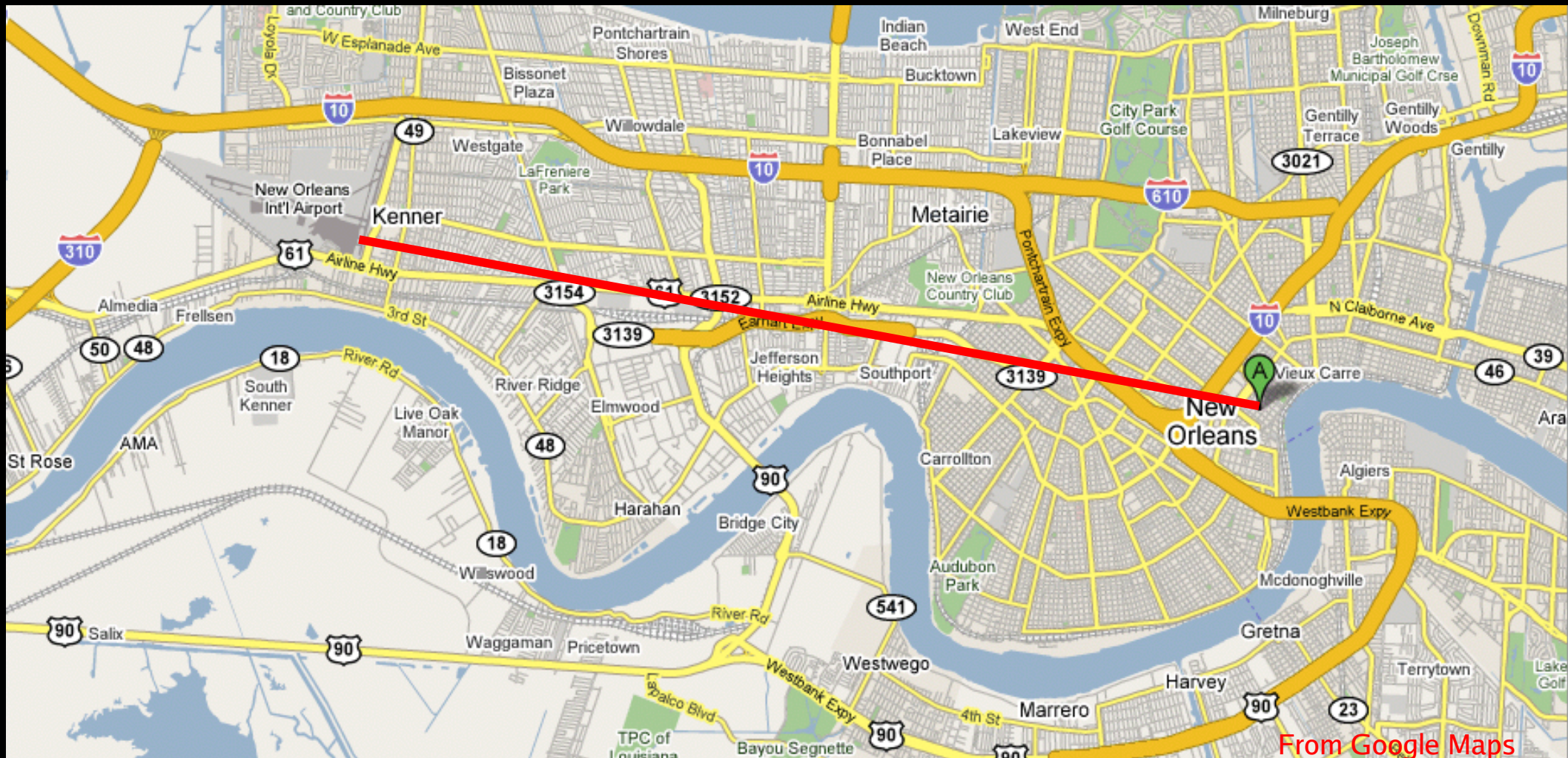
Existing Methods

- Spatial distribution strategies
- Probability distance strategies

- Notation:
  - Anchor point- $\boldsymbol{z} = (z^{(1)}, z^{(2)})$
  - Crime sites- $\boldsymbol{x}_1, \boldsymbol{x}_2, \cdots, \boldsymbol{x}_n$
  - Number of crimes- n

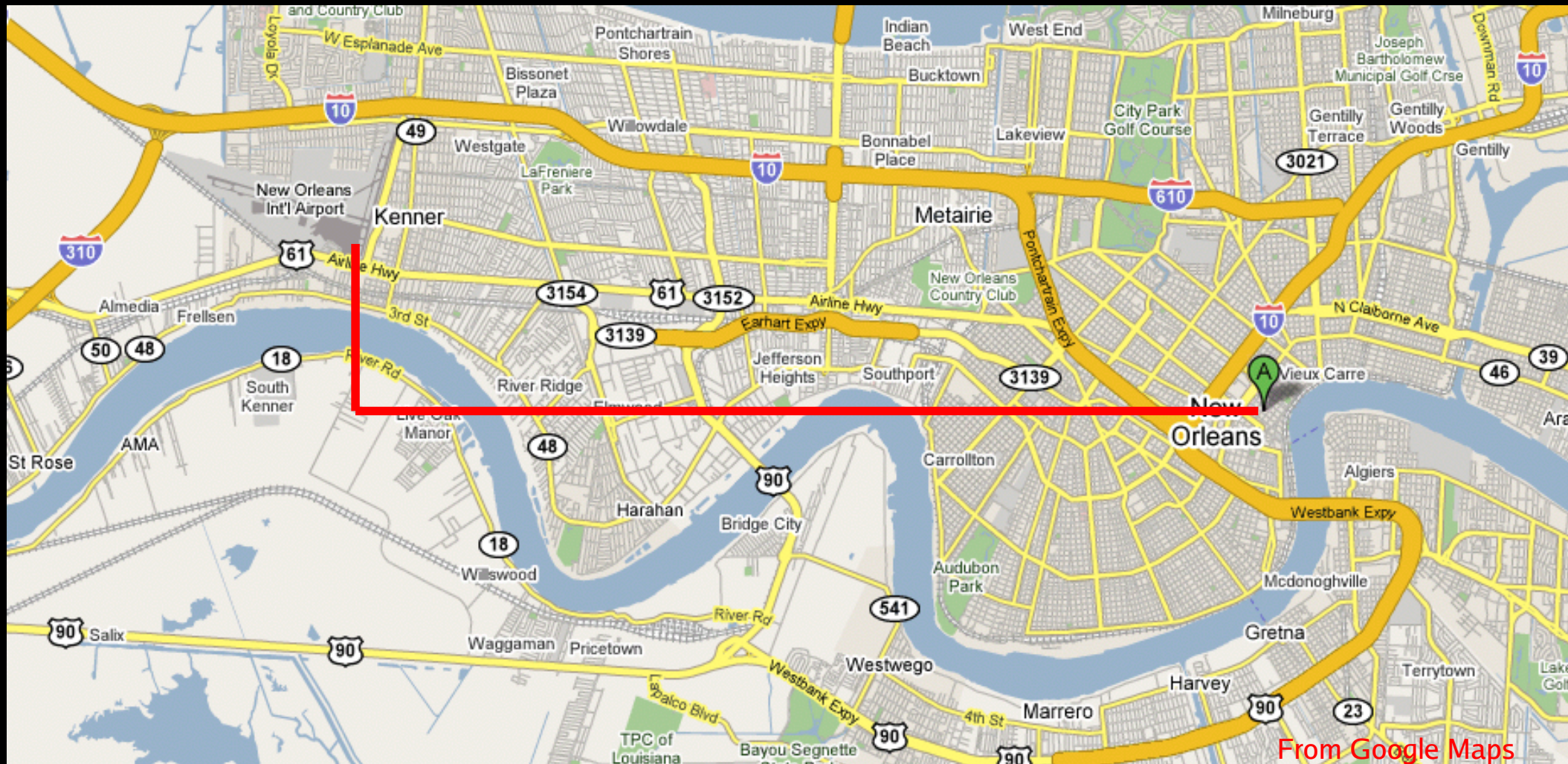
Distance

- How do we measure the distance between points?
  - Euclidean: $d_2(\boldsymbol{x}, \boldsymbol{y}) = \sqrt{(x^{(1)} - y^{(1)})^2 + (x^{(2)} - y^{(2)})^2}$



Distance

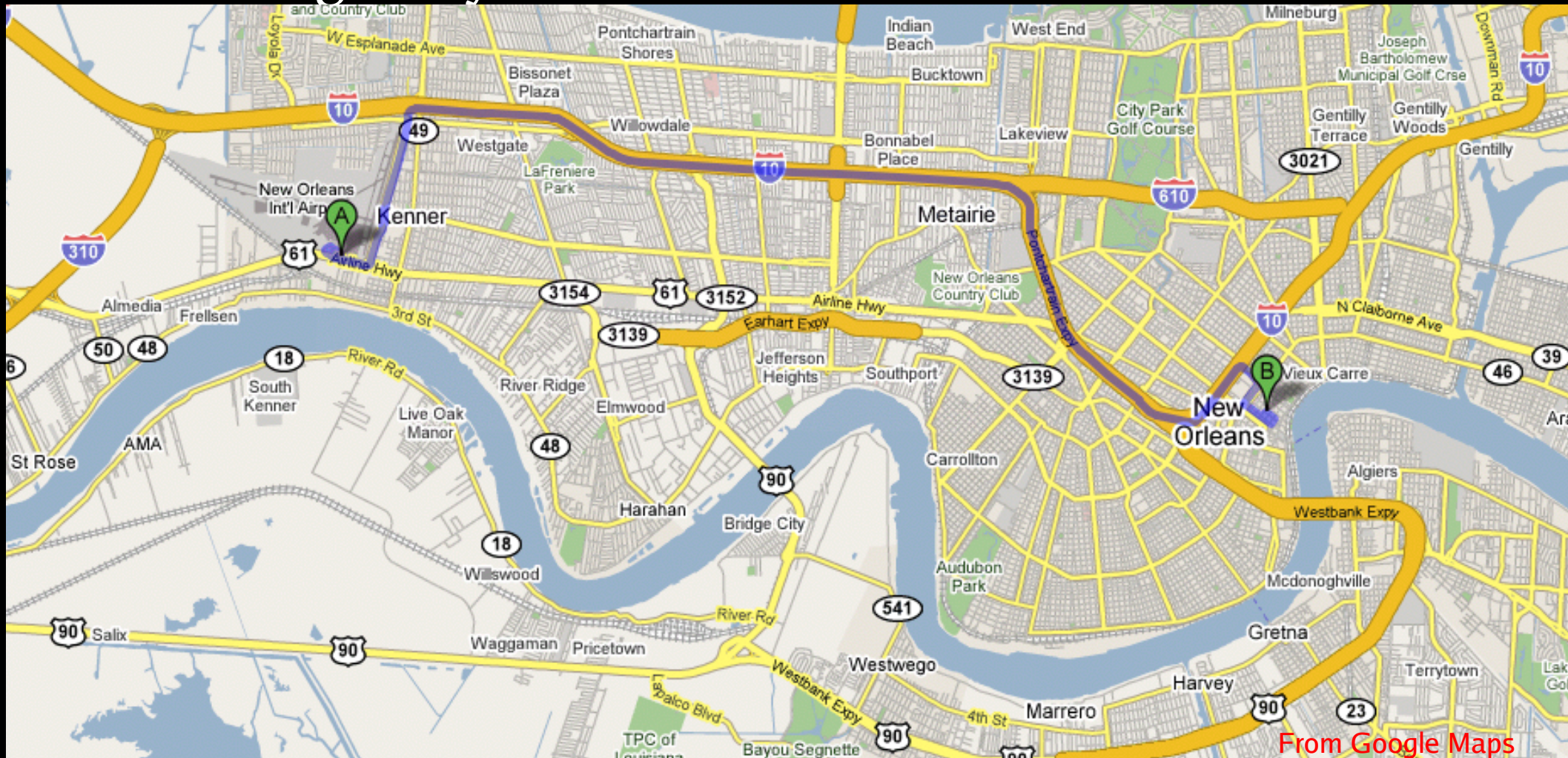
- How do we measure the distance between points?
  - Manhattan: $d_1(\boldsymbol{x}, \boldsymbol{y}) = |x^{(1)} - y^{(1)}| + |x^{(2)} - y^{(2)}|$



From Google Maps

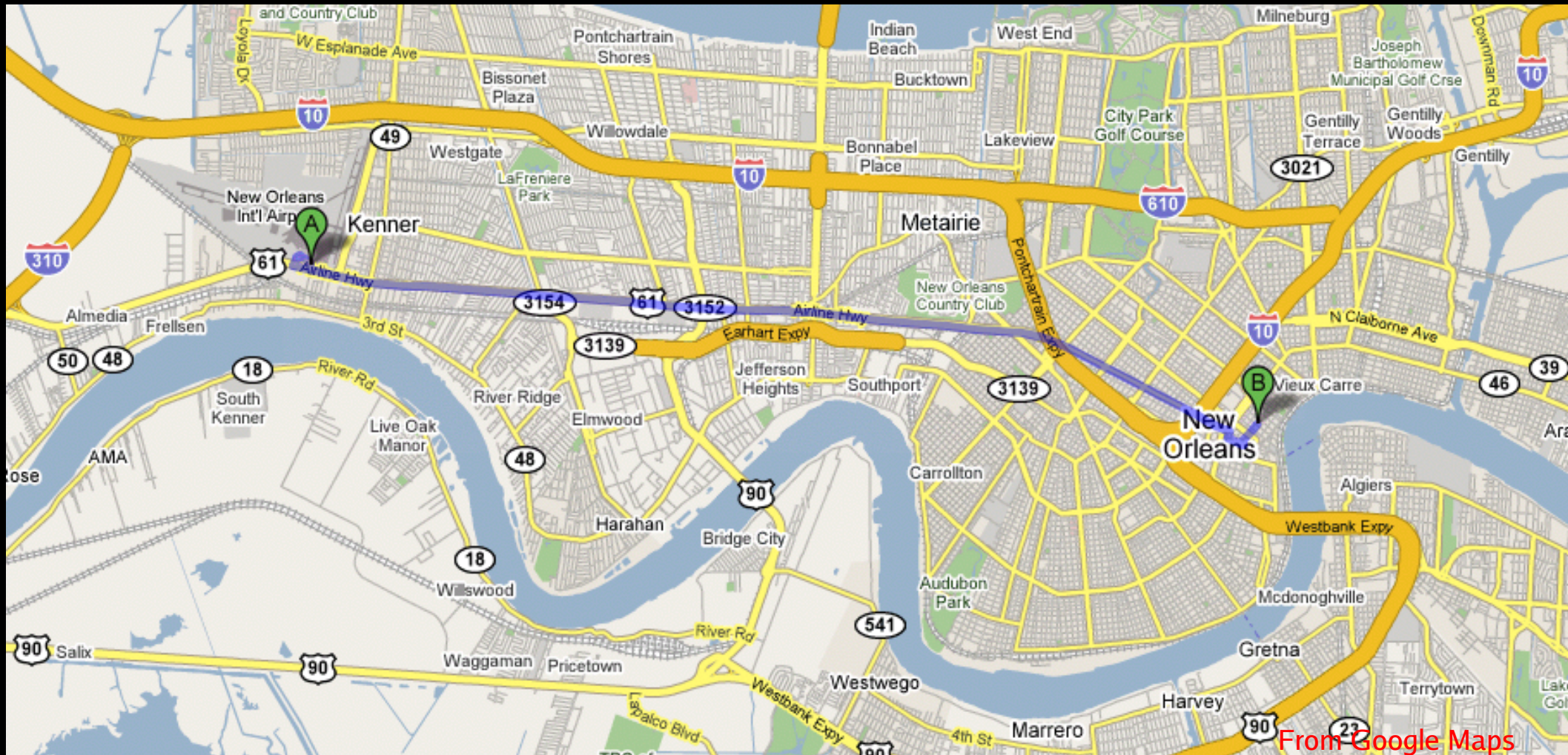
Distance

- How do we measure the distance between points?
  - Highway distance



Distance

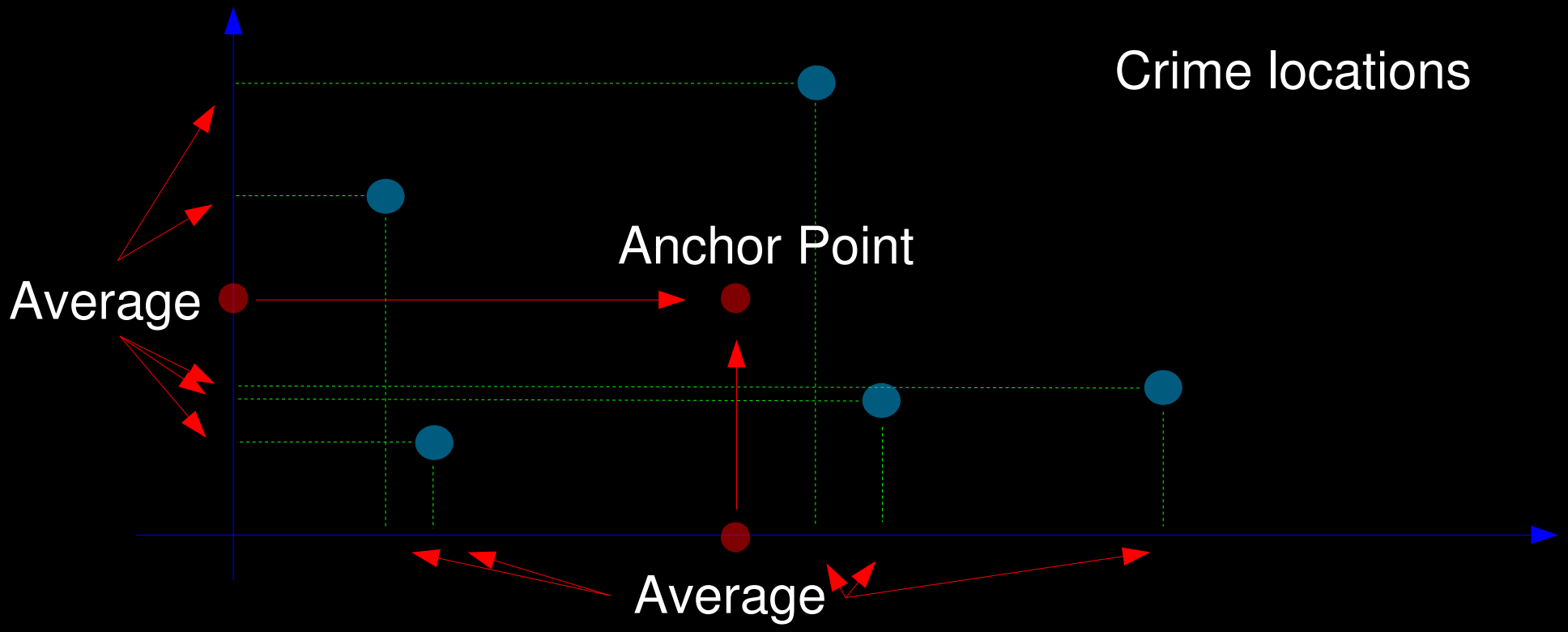
- How do we measure the distance between points?
  - Street distance



Spatial Distribution Strategies

- Centroid:

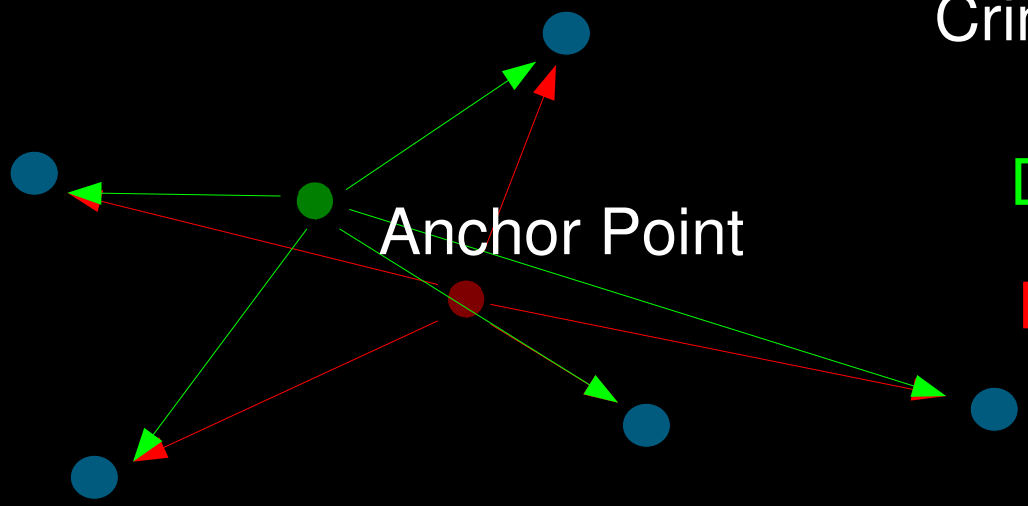
$$\hat{z}_{centroid} = \frac{1}{n}\sum_{i=1}^{n} x_i$$



Spatial Distribution Strategies

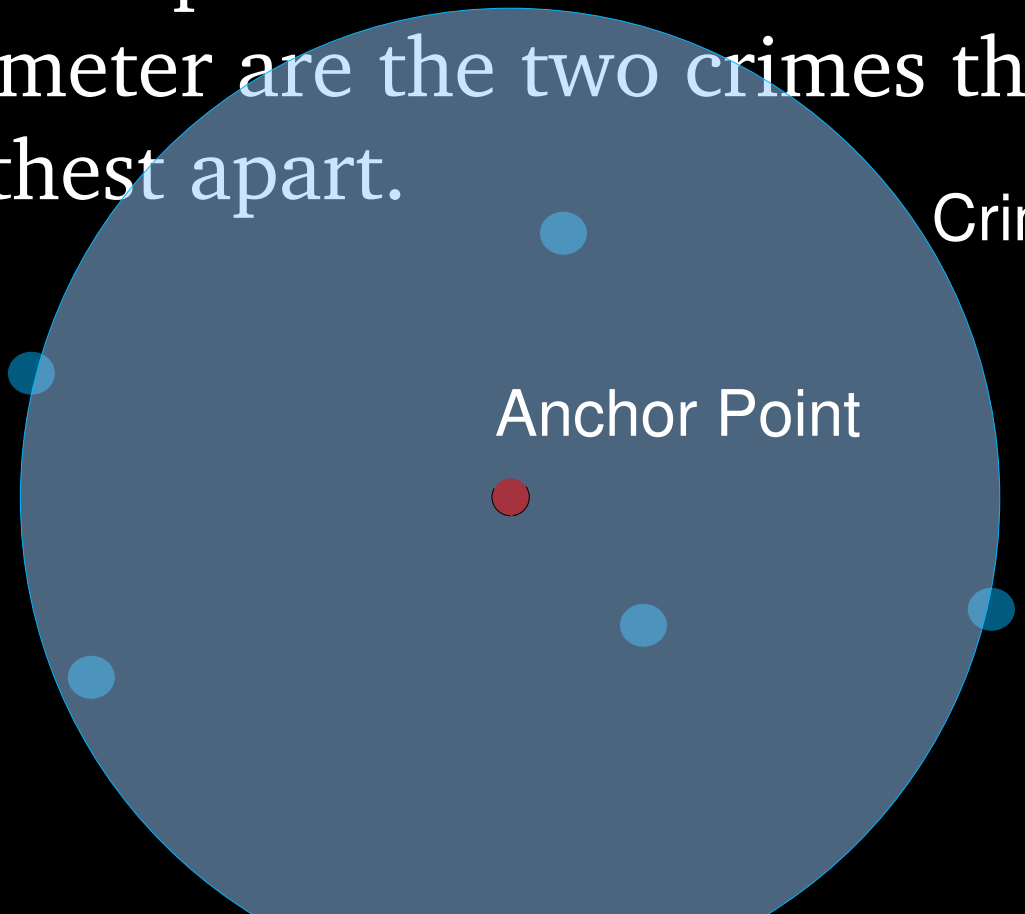
- Center of minimum distance: $\hat{z}_{cmd}$ is the value of y that minimizes

$$D(y)=\sum_{i=1}^{n} d(x_i, y)$$



Spatial Distribution Strategies

- Circle Method (*Canter & Larkin, 1993*):
  - Anchor point contained in the circle whose diameter are the two crimes that are farthest apart.



Probability Distribution Strategies

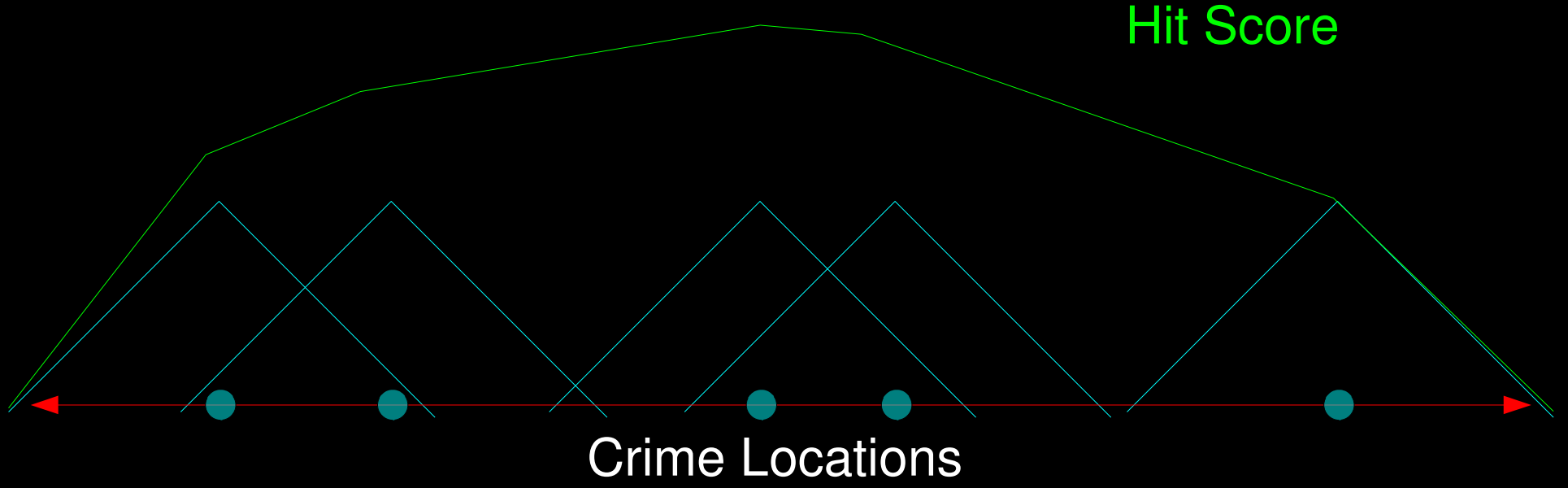
- The anchor point is located in a region with a high “hit score”.
- The hit score $S(\boldsymbol{y})$ has the form

$$S(\boldsymbol{y}) = \sum_{i=1}^{n} f(d(\boldsymbol{y}, \boldsymbol{x}_i))$$
$$= f(d(\boldsymbol{z}, \boldsymbol{x}_1)) + f(d(\boldsymbol{z}, \boldsymbol{x}_2)) + \cdots + f(d(\boldsymbol{z}, \boldsymbol{x}_n))$$

where $\boldsymbol{x}_i$ are the crime locations and f is a decay function and d is a distance.

Probability Distribution Strategies

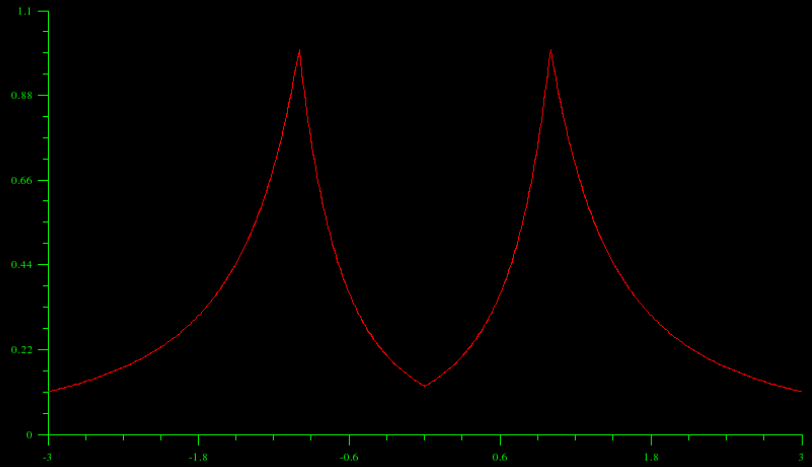
- Linear:
  - $f(d) = A - Bd$



Rossmo (Rigel)

- Manhattan distance metric.
- Decay function

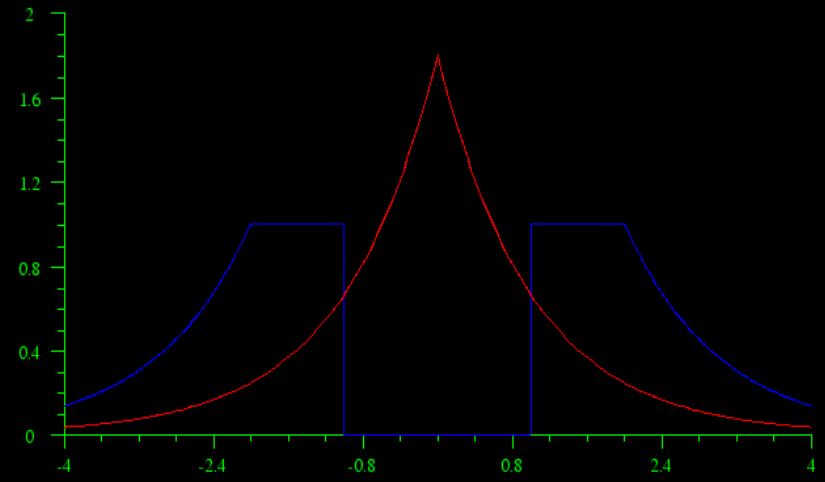
$$f(d)=\begin{cases}\dfrac{k}{d^{h}} & \text{if } d>B \\ \dfrac{k\,B^{g-h}}{(2B-d)^{g}} & \text{if } d\leqslant B\end{cases}$$



- The constants k, g, h and B are empirically defined.

Canter, Coffey, Huntley & Missen (Dragnet)

- Euclidean distance
- Decay functions
  - $f(d) = A e^{-\beta d}$
  - $f(d) = \begin{cases} 0 & \text{if } d < A, \\ 1 & \text{if } A \le d < B, \\ Ce^{-\beta d} & \text{if } d \ge B. \end{cases}$

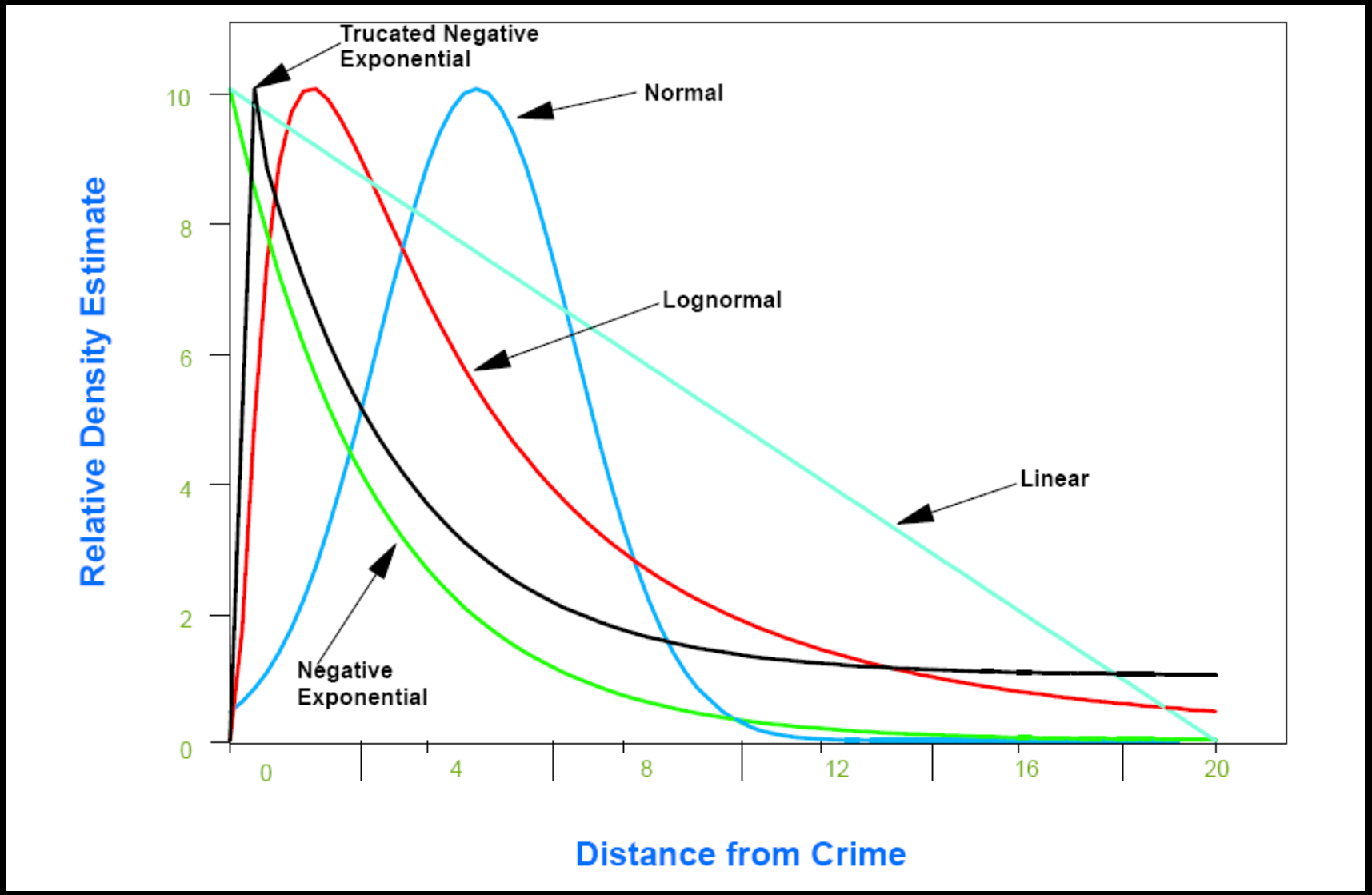


  - Calibrated against homicide data

Levine (CrimeStat)

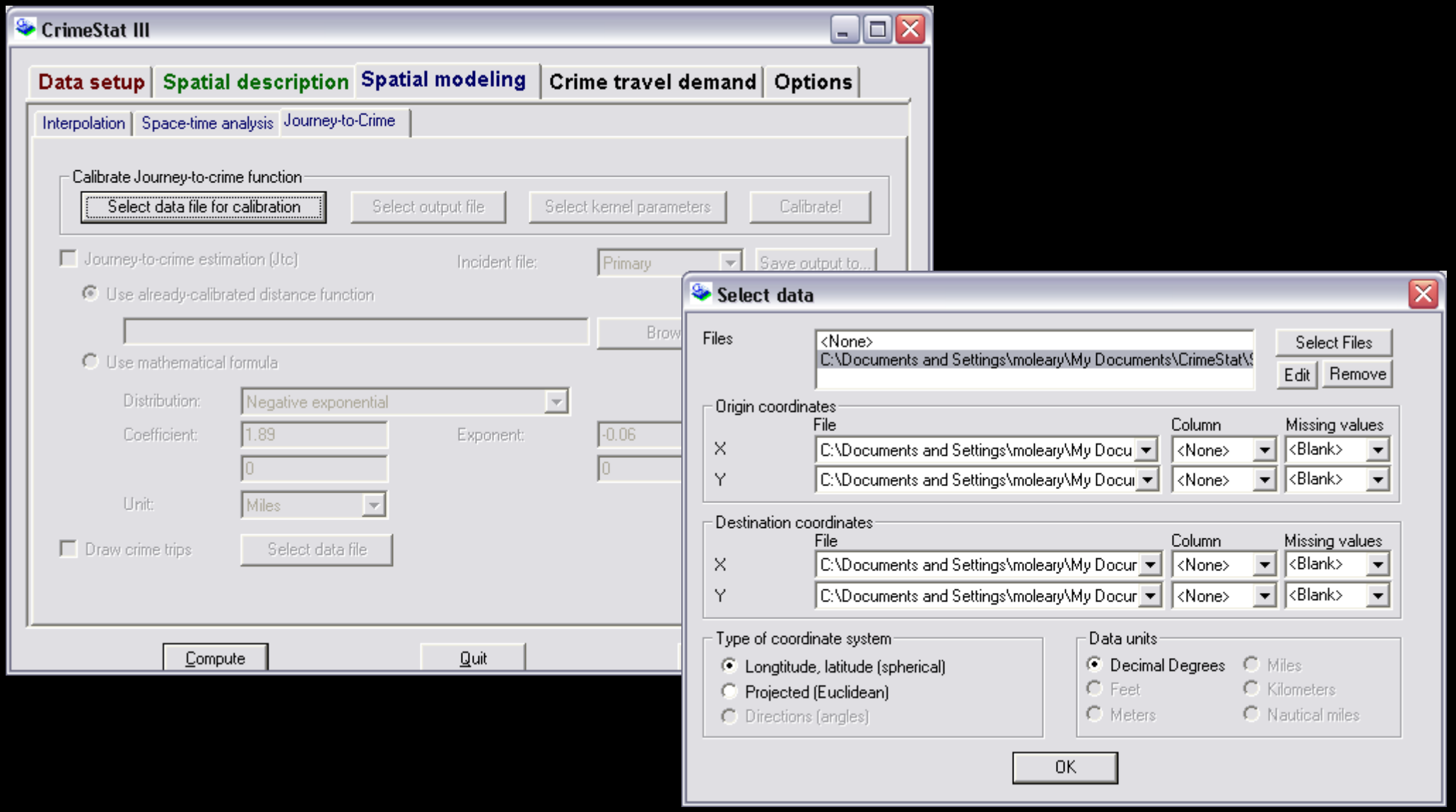
- Euclidean distance
- Decay functions
  - Linear $f(d) = A + Bd$
  - Negative exponential $f(d) = A e^{-\beta d}$
  - Normal $f(d) = \frac{A}{\sqrt{2\pi S^2}} \exp\left[\frac{-(d-\bar{d})^2}{2S^2}\right]$
  - Lognormal $f(d) = \frac{A}{d\sqrt{2\pi S^2}} \exp\left[\frac{-(\ln d-\bar{d})^2}{2S^2}\right]$

Levine (CrimeStat)



From Levine (2004)

CrimeStat


CrimeStat III
Data setup
Spatial description
Spatial modeling
Crime travel demand
Options
Interpolation
Space-time analysis
Journey-to-Crime
Calibrate Journey-to-crime function
Select data file for calibration
Select output file
Select kernel parameters
Calibrate!
Journey-to-crime estimation (Jtc)
Incident file:
Primary
Save output to...
Use already-calibrated distance function
Brow
Use mathematical formula
Distribution:
Negative exponential
Coefficient:
1.89
Exponent:
-0.06
0
0
Unit:
Miles
Draw crime trips
Select data file
Compute
Quit
Select data
Files
<None>
C:\Documents and Settings\moleary\My Documents\CrimeStat\
Select Files
Edit
Remove
Origin coordinates
File
Column
Missing values
X
C:\Documents and Settings\moleary\My Docu
<None>
<Blank>
Y
C:\Documents and Settings\moleary\My Docu
<None>
<Blank>
Destination coordinates
File
Column
Missing values
X
C:\Documents and Settings\moleary\My Docur
<None>
<Blank>
Y
C:\Documents and Settings\moleary\My Docur
<None>
<Blank>
Type of coordinate system
Longtitude, latitude (spherical)
Projected (Euclidean)
Directions (angles)
Data units
Decimal Degrees
Miles
Feet
Kilometers
Meters
Nautical miles
OK

Probability Distribution Strategies

- Existing methods differ in their choices of
  - The distance measure, and
  - The distance decay function;

but share the common mathematical heritage:

$$S(\boldsymbol{y}) = \sum_{i=1}^{n} f(d(\boldsymbol{y}, \boldsymbol{x}_i))$$

- In practice, $S(\boldsymbol{y})$ may be evaluated only at discrete values $\boldsymbol{y}_j$ giving us a hit score matrix

$$S_{ij} = \sum_{i=1}^{n} f(d(\boldsymbol{y}_j, \boldsymbol{x}_i))$$

Controversies

- What is the right tool?

Abt

A Methodology for Evaluating Geographic Profiling Software

An Evaluation of NIJ's Evaluation Methodology for Geographic Profiling Software

May 8, 2005

D. Kim Rossmo
Research Professor and Directo
Center for Geospatial Intelligence and In
Department of Criminal Justic
Texas State University

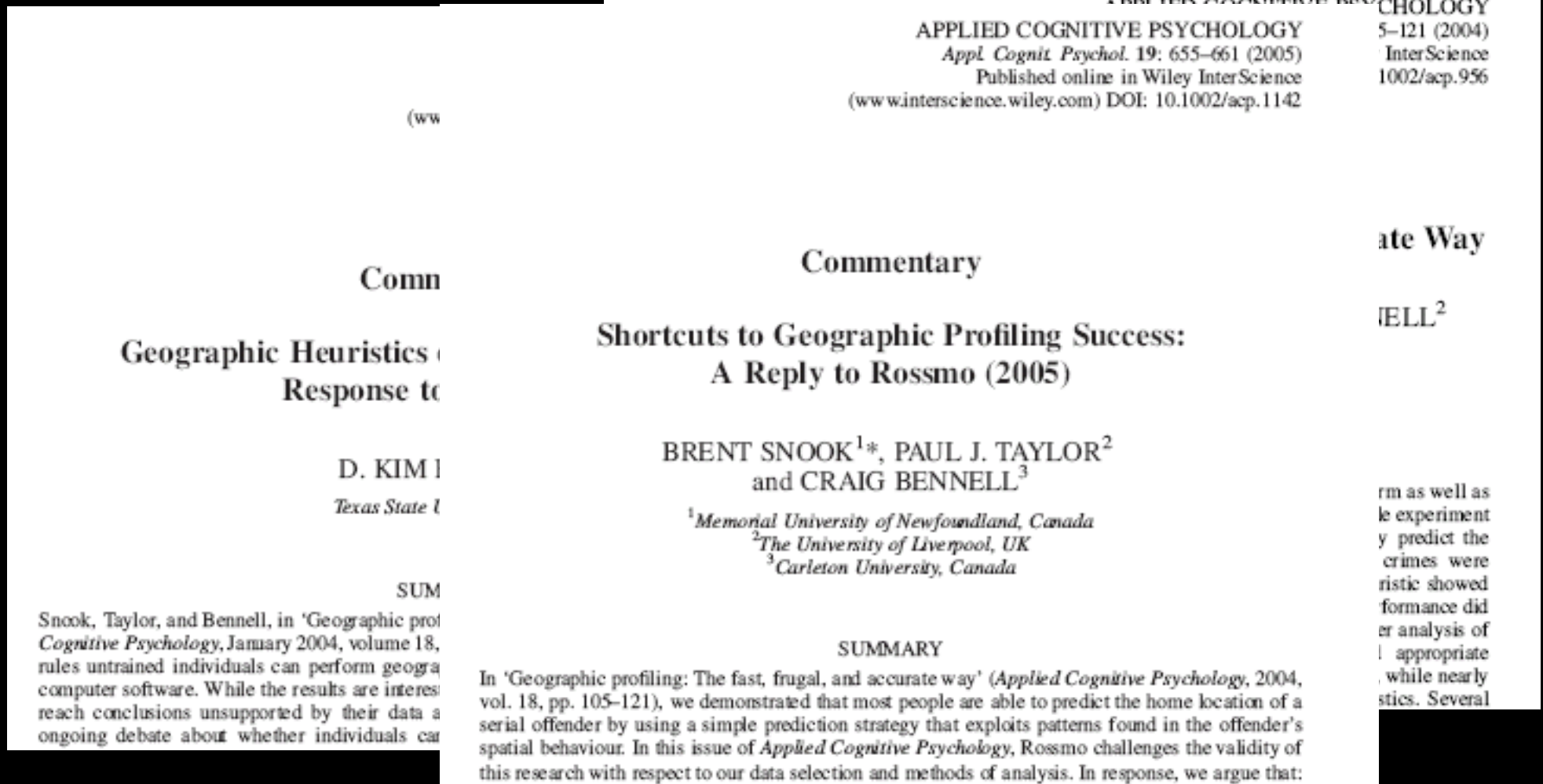
The Evaluation of Geographic Profiling Software:
1Response to Kim Rossmo's Critique of the NIJ Methodology

The recent discussion of geographical profiling (GP) methodology has been a testament to the contribution that Kim Rossmo made in critiquing the GP roundtable discussion that was posted on the MAPS website. I've had some time to think about his critique and would like to offer some thoughts.

Let me first start by saying that I had nothing to do with the GP roundtable even though my CrimeStat Journey to Crime (Jtc) was one of the tested methods (what Rossmo calls 'the NIJ methodology'). Like any developer, there are things that the roundtable evaluation did that I wouldn't necessarily agree with. But, that's the prerogative of an evaluator and usually just shows that there is more than one way to do things.

Controversies

- Are they *operationally* effective?



(ww

Comn

Geographic Heuristics
Response to

D. KIM

Texas State

SUM

Snook, Taylor, and Bennell, in 'Geographic prof
Cognitive Psychology, January 2004, volume 18,
rules untrained individuals can perform geogra
computer software. While the results are interes
reach conclusions unsupported by their data a
ongoing debate about whether individuals ca

CHOLOGY
5–121 (2004)
InterScience
1002/acp.956

ate Way

ELL[2]

rm as well as
le experiment
y predict the
crimes were
ristic showed
formance did
er analysis of
appropriate
while nearly
stics. Several

APPLIED COGNITIVE PSYCHOLOGY
Appl. Cognit. Psychol. **19**: 655–661 (2005)
Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/acp.1142

Commentary

Shortcuts to Geographic Profiling Success: A Reply to Rossmo (2005)

BRENT SNOOK[1]*, PAUL J. TAYLOR[2] and CRAIG BENNELL[3]

[1]*Memorial University of Newfoundland, Canada*
[2]*The University of Liverpool, UK*
[3]*Carleton University, Canada*

SUMMARY

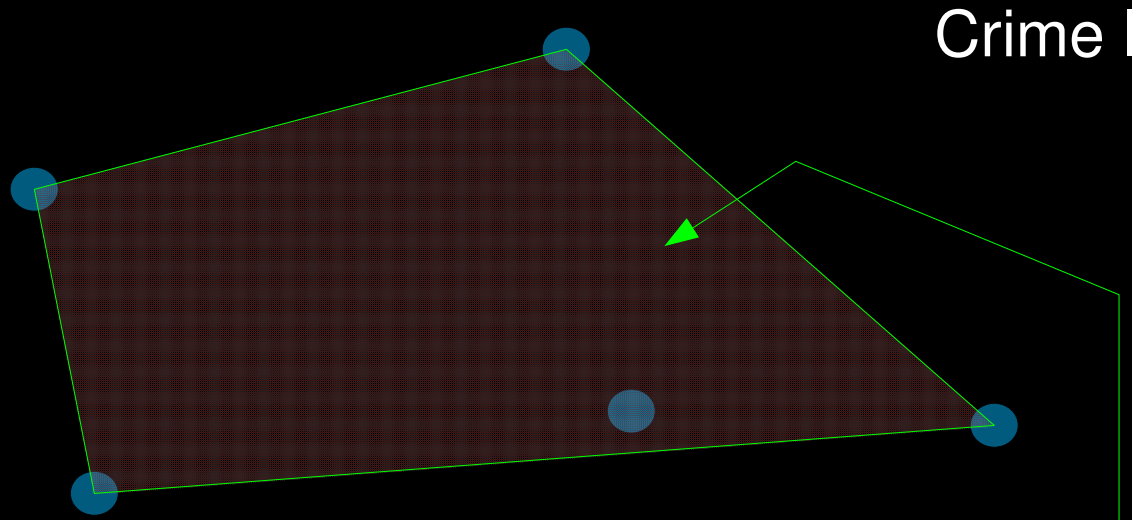
In 'Geographic profiling: The fast, frugal, and accurate way' (*Applied Cognitive Psychology*, 2004, vol. 18, pp. 105–121), we demonstrated that most people are able to predict the home location of a serial offender by using a simple prediction strategy that exploits patterns found in the offender's spatial behaviour. In this issue of *Applied Cognitive Psychology*, Rossmo challenges the validity of this research with respect to our data selection and methods of analysis. In response, we argue that:

Shortcomings

- These techniques are all *ad hoc*.
- What is their theoretical justification?
  - What assumptions are being made about criminal behavior?
  - What mathematical assumptions are being made?

Shortcomings

- The convex hull effect:
  - The anchor point always occurs inside the convex hull of the crime locations.



Shortcomings

- These methods require some *a priori* knowledge of the offender's distance decay function.
  - In particular, they require an estimate of the distance that the serial offender is likely to travel before the analysis process begins.
  - Indeed, the constant(s) that appear in the distance decay function must be selected before starting the analysis.

Shortcomings

- How do you add in local information?
  - How could you incorporate socio-economic variables into the model?

Snook, *Individual differences in distance travelled by serial burglars*
Malczewski, Poetz & Iannuzzi, *Spatial analysis of residential burglaries in London, Ontario*
Bernasco & Nieuwbeerta, *How do residential burglars select target areas?*
Osborn & Tseloni, *The distribution of household property crimes*

Geographic Profiling

- What characteristics should a good geographic profiling method possess?

1. It should be mathematically rigorous.
2. There should be explicit connections between assumptions on offender behavior and components of the mathematical model.

Geographic Profiling

- What (other) characteristics should a good geographic profiling technique possess?

3. It should take into account local geographic features that affect:
    a. The selection of a crime site;
    b. The selection of an anchor point.
4. It should rely only on data available to local law enforcement.
5. It should return a prioritized search area.

Main Result

- We have developed a fundamentally new mathematical technique for geographic profiling.
  - We have implemented the algorithm in software, and begun testing it on actual crime series.

A New Approach

- Let us start with a model of offender behavior.
  - In particular, let us begin with the ansatz that an offender with anchor point $\boldsymbol{z}$ commits a crime at the location $\boldsymbol{x}$ according to a probability density function $P(\boldsymbol{x} \mid \boldsymbol{z})$.
  - This is an inherently continuous model.

Modeling with Probability

- Probabilistic models are commonly used to model problems that are deterministic.
  - Stock market
  - Population genetics
  - Heat flow
  - Chemical diffusion

A New Approach

- Assumptions about
  - The offender's likely behavior, and
  - The local geography

can then be incorporated into the form of $P(\boldsymbol{x} \mid \boldsymbol{z})$.

The Mathematics

- Given crimes located at $x_1, x_2, \cdots, x_n$ the *maximum likelihood estimate* for the anchor point $\hat{z}_{mle}$ is the value of y that maximizes

$$L(y) = \prod_{i=1}^{n} P(x_i \mid y)$$

$$= P(x_1 \mid y) P(x_2 \mid y) \cdots P(x_n \mid y)$$

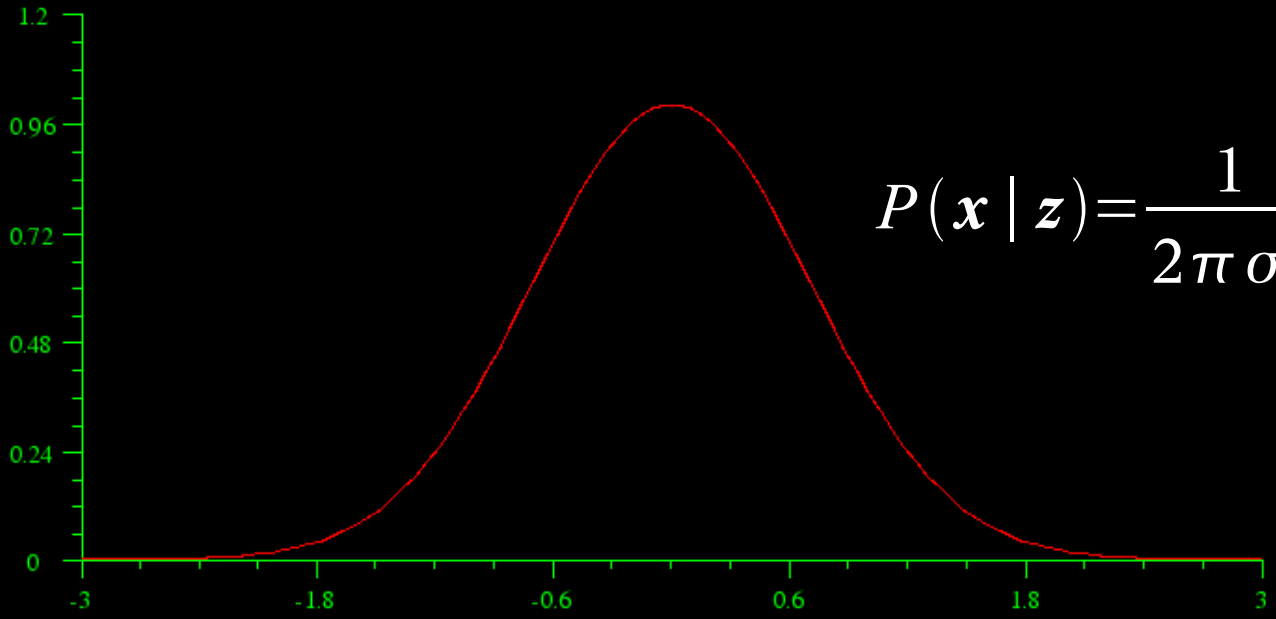
or equivalently, the value that maximizes

$$\lambda(y) = \sum_{i=1}^{n} \ln P(x_i \mid y)$$

$$= \ln P(x_1 \mid y) + \ln P(x_2 \mid y) + \cdots + \ln P(x_n \mid y)$$

Relation to Spatial Distribution Strategies

- If we assume offenders choose target locations based only on a distance decay function in normal form:

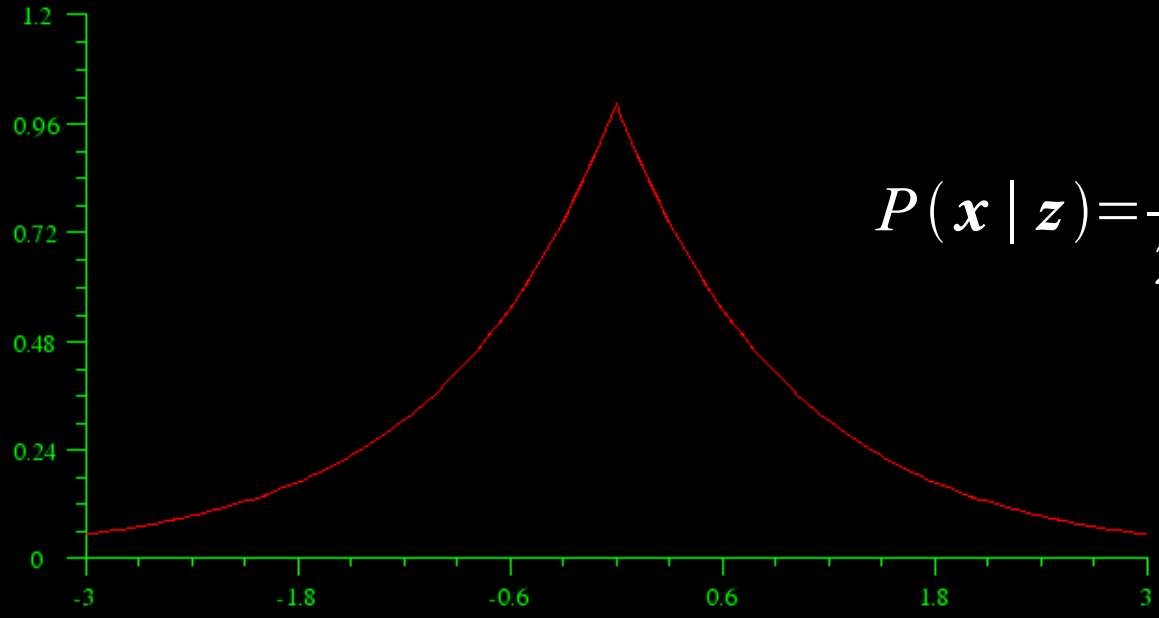


$$P(\boldsymbol{x} \mid \boldsymbol{z}) = \frac{1}{2\pi\sigma^2} \exp\left[-\frac{|\boldsymbol{x}-\boldsymbol{z}|^2}{2\sigma^2}\right]$$

- Then the maximum likelihood estimate for the anchor point is the centroid.

Relation to Spatial Distribution Strategies

- If we assume offenders choose target locations based only on a distance decay function in exponentially decaying form:



$$P(\boldsymbol{x} \mid \boldsymbol{z}) = \frac{1}{2\pi\sigma^2} \exp\left[-\frac{|\boldsymbol{x}-\boldsymbol{z}|}{\sigma}\right]$$

- Then the maximum likelihood estimate is the center of minimum distance.

Relation to Probability Distance Strategies

- What is the log likelihood function?

$$\lambda(\boldsymbol{y}) = \sum_{i=1}^{n} \left[-\ln(2\pi\sigma^2) - \frac{|\boldsymbol{x}_i - \boldsymbol{y}|}{\sigma} \right]$$

- This is the hit score $S(\boldsymbol{y})$ provided we use Euclidean distance and the linear decay $f(d) = A + Bd$ for

$$A = -\ln(2\pi\sigma^2)$$
$$B = -1/\sigma$$

Parameters

- The maximum likelihood technique does not require *a priori* estimates for parameters other than the anchor point.

$$P(\boldsymbol{x} \mid \boldsymbol{z}, \sigma) = \frac{1}{2\pi\sigma^2} \exp\left[-\frac{|\boldsymbol{x}-\boldsymbol{z}|^2}{2\sigma^2}\right]$$

The same process that determines the best choice of $\boldsymbol{z}$ also determines the best choice of σ.

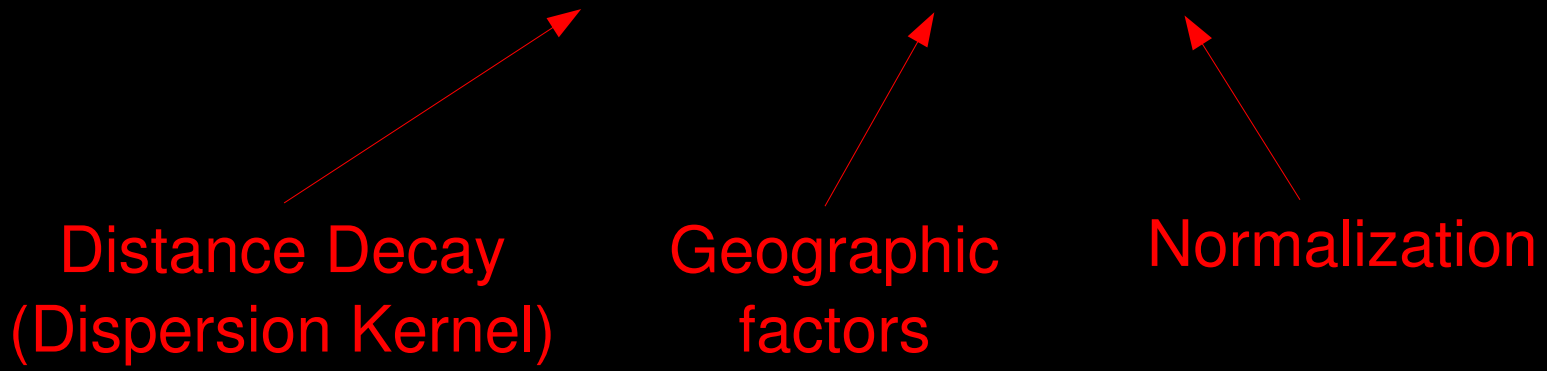
Better Models

- We have recaptured the results of existing techniques by choosing $P(\boldsymbol{x} \mid \boldsymbol{z})$ appropriately.
- These choices of $P(\boldsymbol{x} \mid \boldsymbol{z})$ are not very realistic.
  - Space is homogeneous and crimes are equi-distributed.
  - Space is infinite.
  - Decay functions were chosen arbitrarily.

Better Models

- Our framework allows for better choices of $P(\boldsymbol{x} \mid \boldsymbol{z})$.
- Consider

$$P(\boldsymbol{x} \mid \boldsymbol{z}) = D(d(\boldsymbol{x}, \boldsymbol{z})) \cdot G(\boldsymbol{x}) \cdot N(z)$$



Geography

- What geographic factors should be included in the model?

  Snook, *Individual differences in distance travelled by serial burglars*
  Malczewski, Poetz & Iannuzzi, *Spatial analysis of residential burglaries in London, Ontario*
  Bernasco & Nieuwbeerta, *How do residential burglars select target areas?*
  Osborn & Tseloni, *The distribution of household property crimes*

Geography

- This approach has some problems.
  - Different crimes have different etiologies.
    - We would need to study each different crime type.
  - There are regional differences.
    - Tseloni, Wittebrood, Farrell and Pease (2004) noted that increased household affluence indicated higher burglary rates in Britain, and indicated lower burglary rates in the U.S.

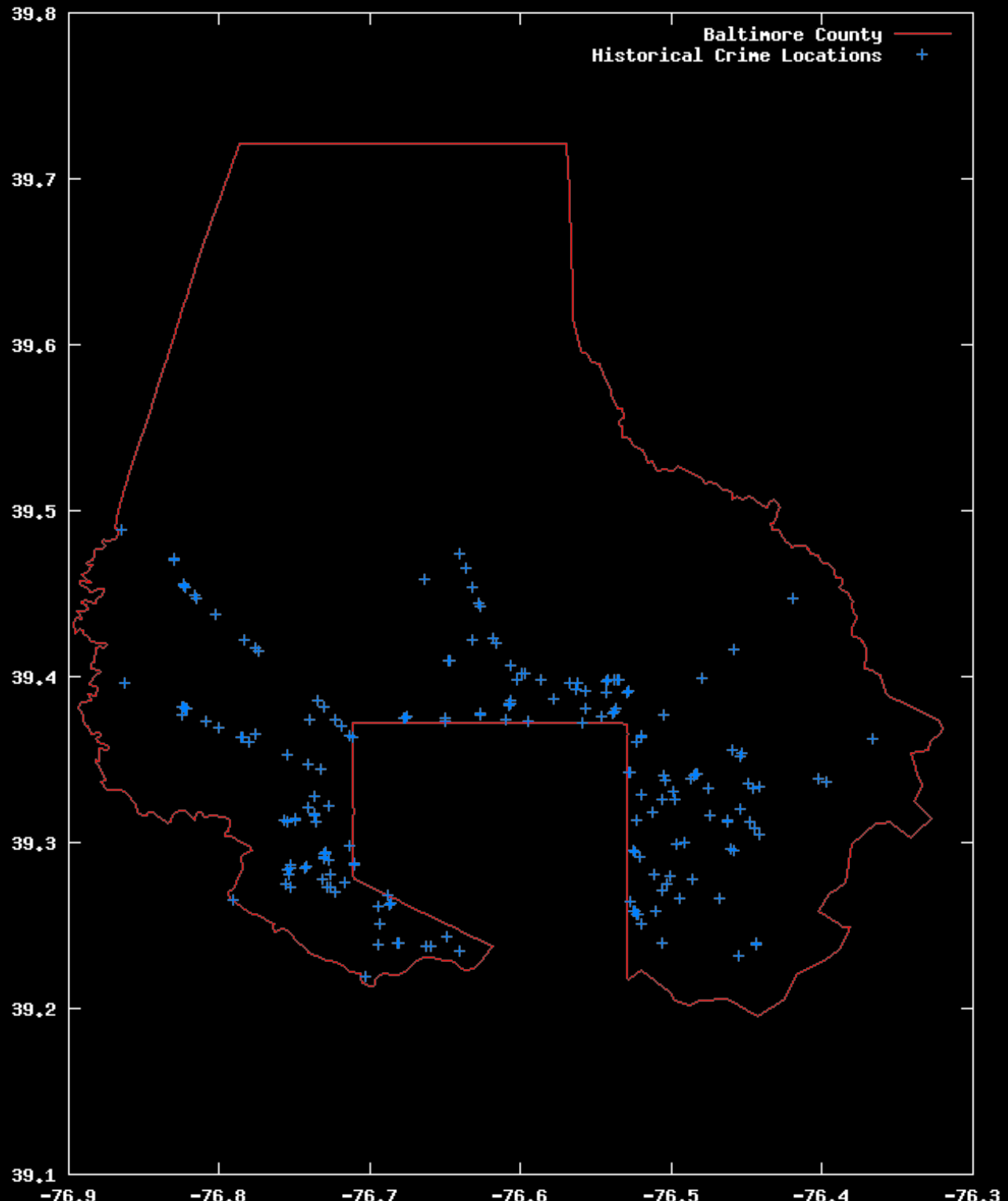
Geography

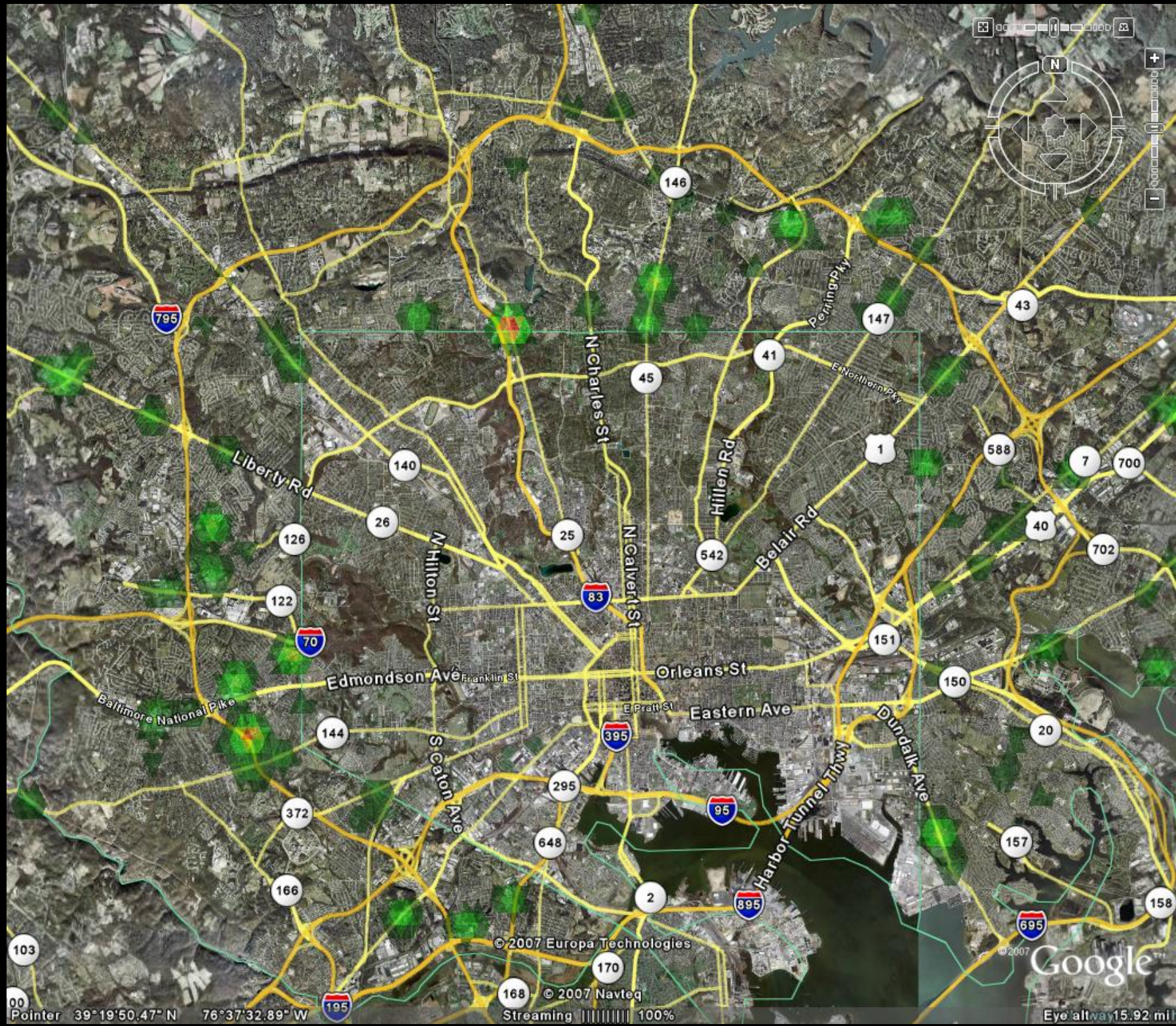
- Instead, we assume that historical crime rates are reasonable predictors of the likelihood that a particular region will be the site of an offense.
  - Rather than explain crime rates in terms of underlying geographic variables, we simply measure the resulting geographic variability.
- Let $G(x)$ represent the local attractiveness of potential targets.

Geography

- An analyst can determine what historical data should be used to generate the geographic target density function.
  - Different crime types will necessarily generate different functions $G(x)$.
- $G(x)$ is calculated in the same fashion as hot spots; *e.g.* by kernel density parameter estimation.

$$G(x) = \sum_{i=1}^{N} K(x - y_i)$$


Baltimore County
Historical Crime Locations
39.8
39.7
39.6
39.5
39.4
39.3
39.2
39.1
-76.9
-76.8
-76.7
-76.6
-76.5
-76.4
-76.3



Liberty Rd
N Hilton St
N Charles St
N Calvert St
Hillen Rd
Belair Rd
Perring Pky
E Northern Pky
Edmondson Ave
Franklin St
Orleans St
E Pratt St
Eastern Ave
Baltimore National Pike
S Caton Ave
Harbor Tunnel Thwy
Dundalk Ave
795
70
83
395
95
895
695
195
146
147
43
41
45
1
588
7
700
140
26
126
25
542
40
702
122
151
150
20
144
295
372
648
157
166
2
158
103
170
168
© 2007 Europa Technologies
© 2007 Navteq
Google
Pointer 39°19'50.47" N 76°37'32.89" W
Streaming 100%
Eye alt 15.92 mi

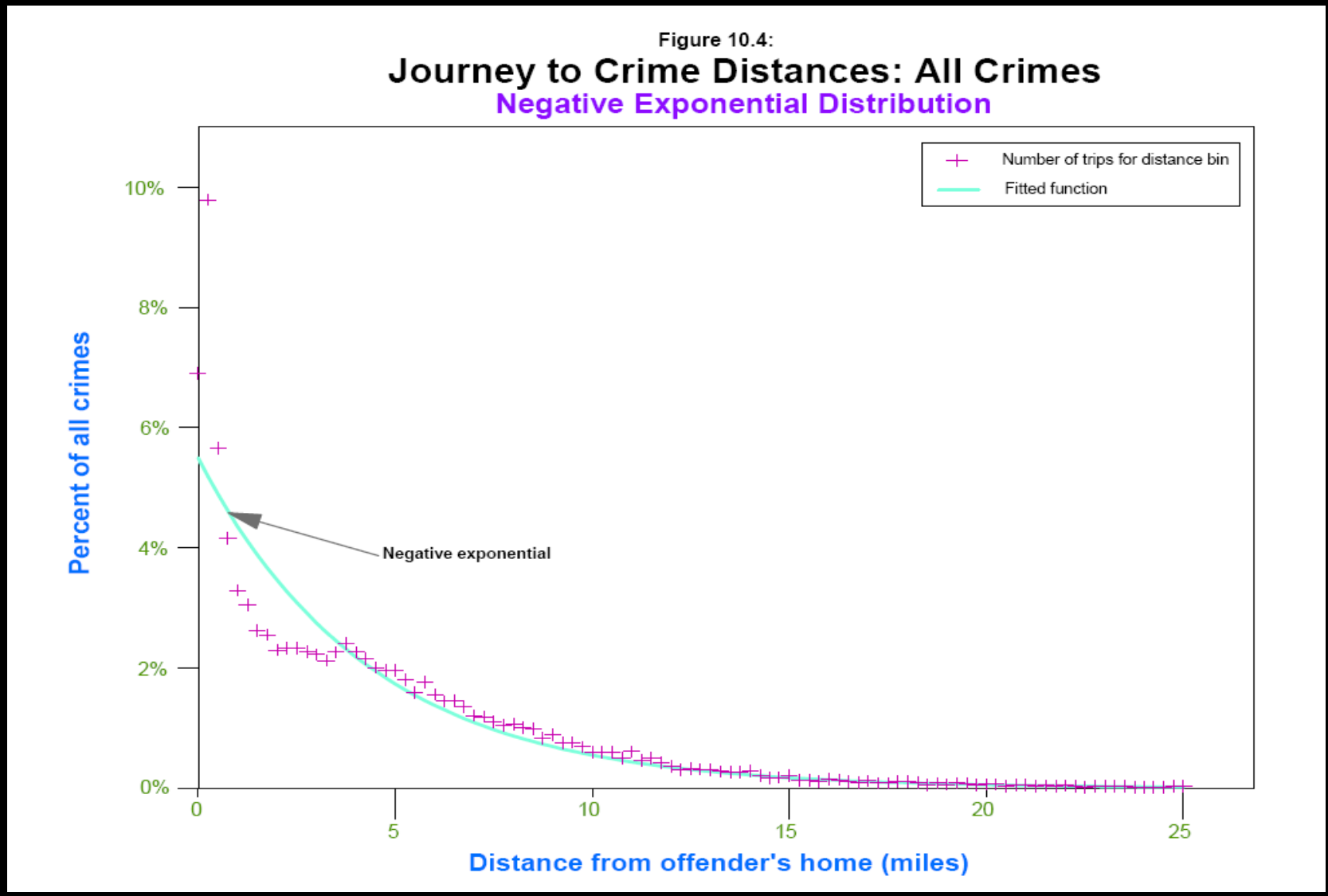
Geography

- The target attractiveness $G(x)$ must also account for jurisdictional boundaries.
  - Suppose that a law enforcement agency gets reports for all crimes within the region J, and none from outside J.
  - Then we must have

$$G(x)=0 \quad \text{for all } x \notin J$$

as no crimes that occur outside J will be known to that agency.

Distance Decay

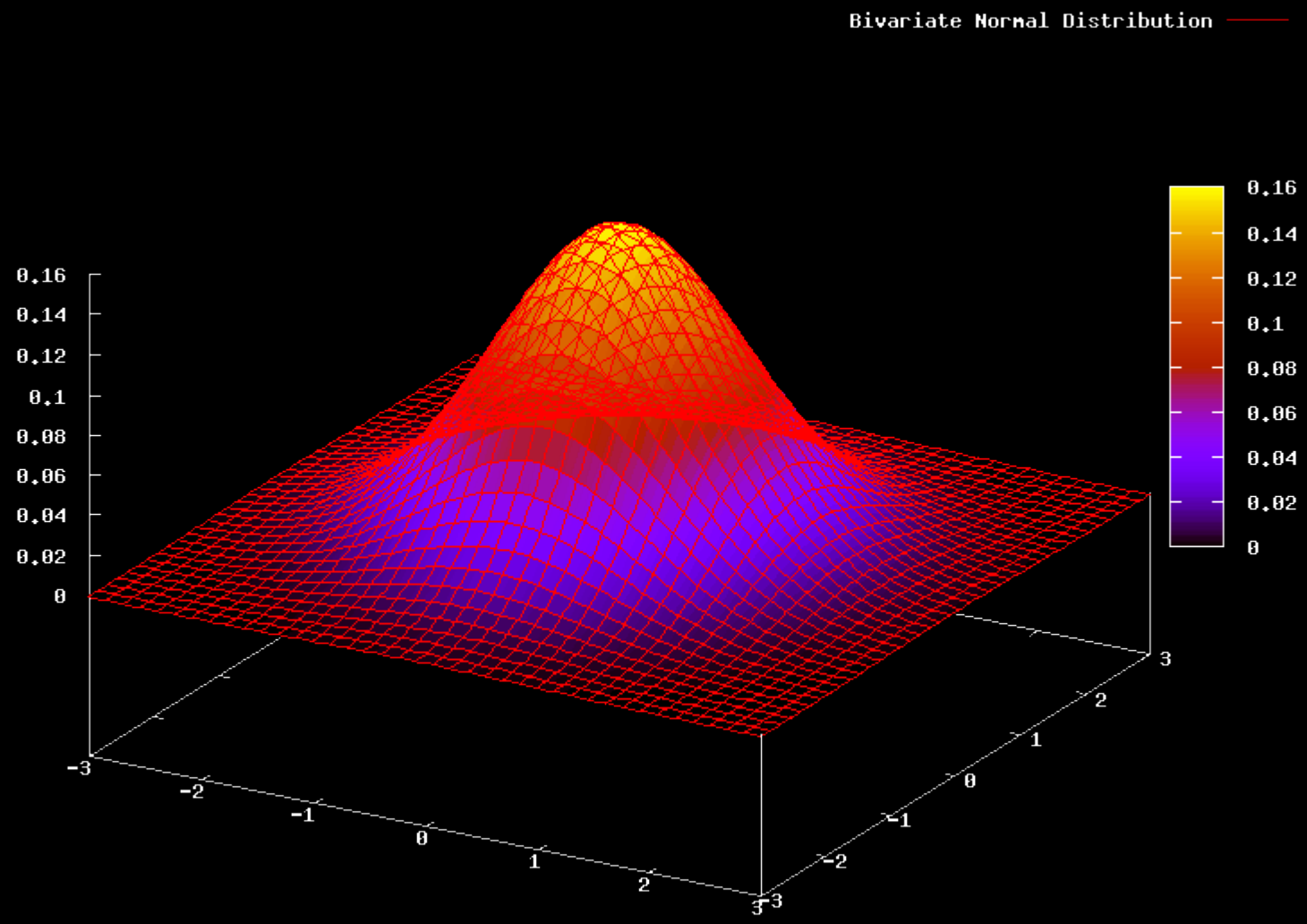


From Levine (2004)

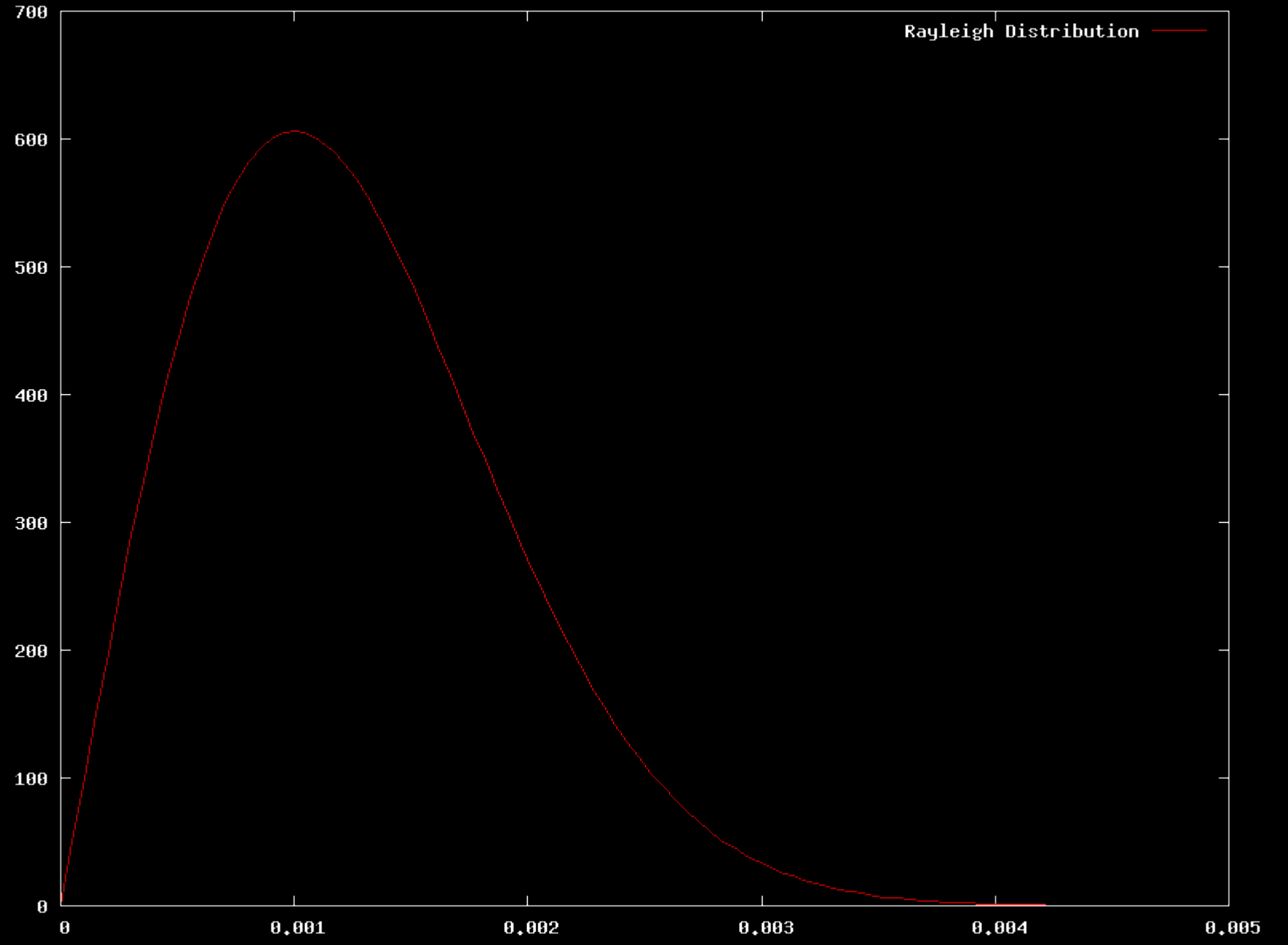
Distance Decay

- Buffer Zones
  - A region around the offenders anchor point where they are less likely to offend.
  - Fear of recognition.

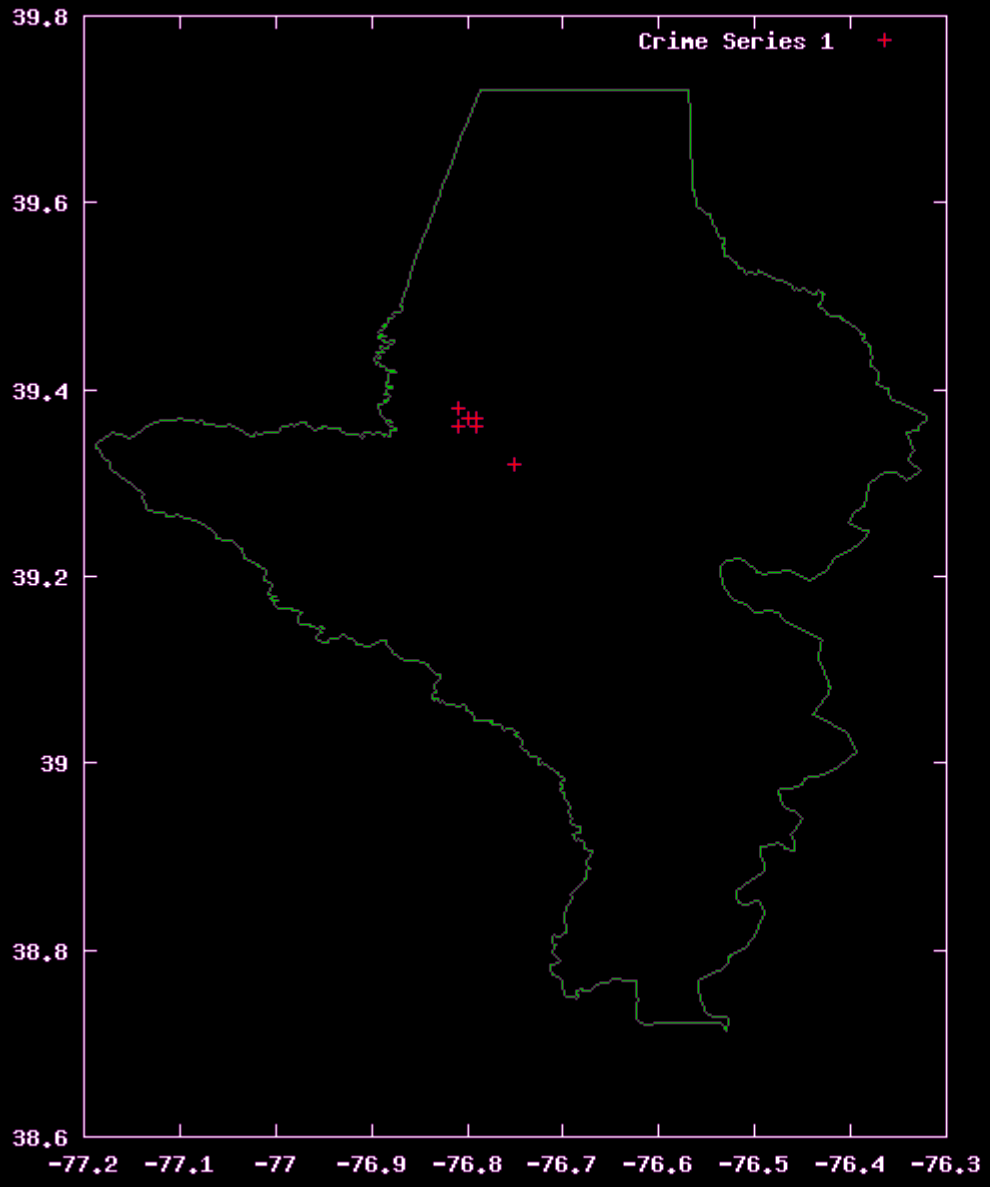
Distance Decay: Buffer Zones



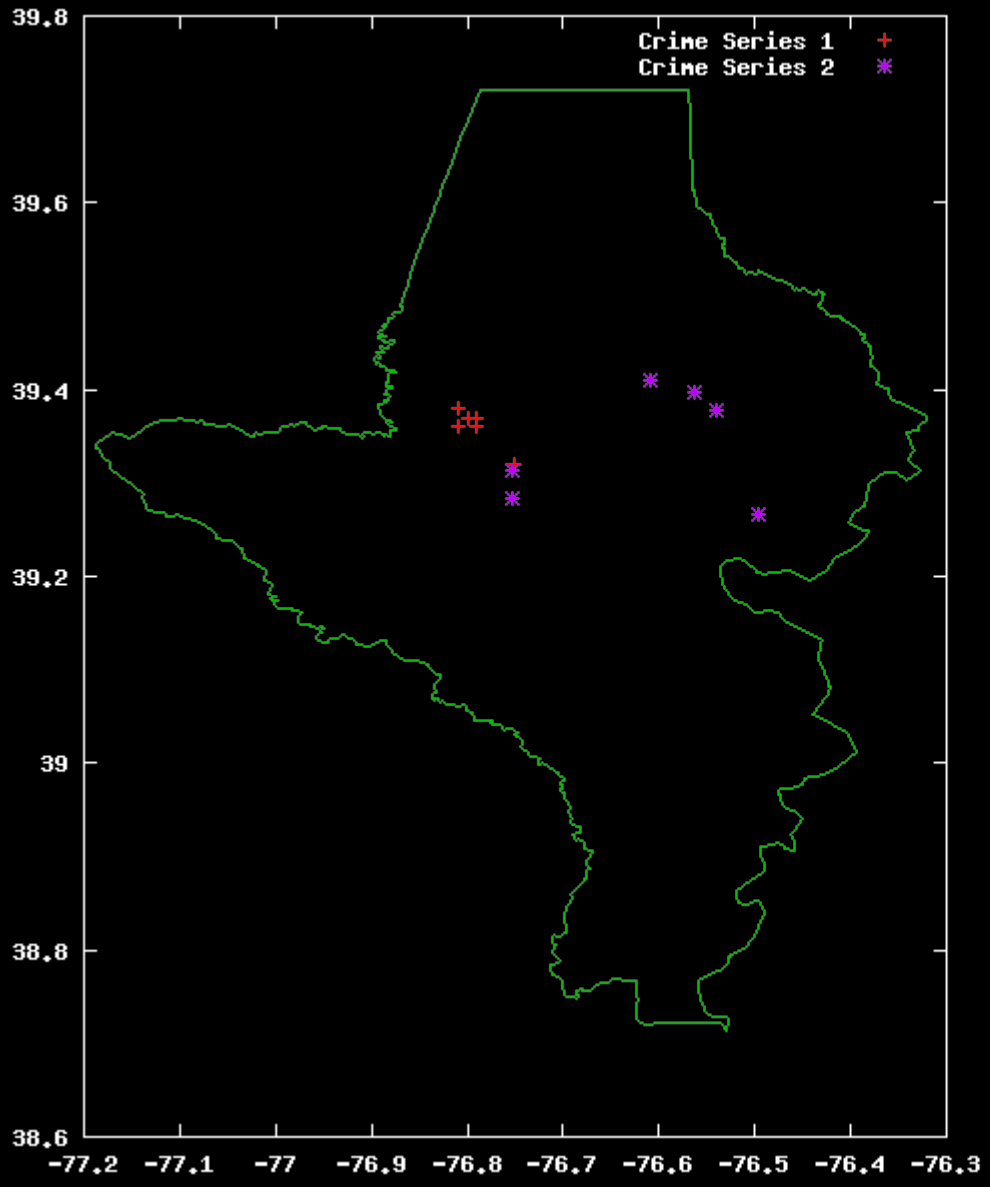
Distance Decay: Buffer Zones



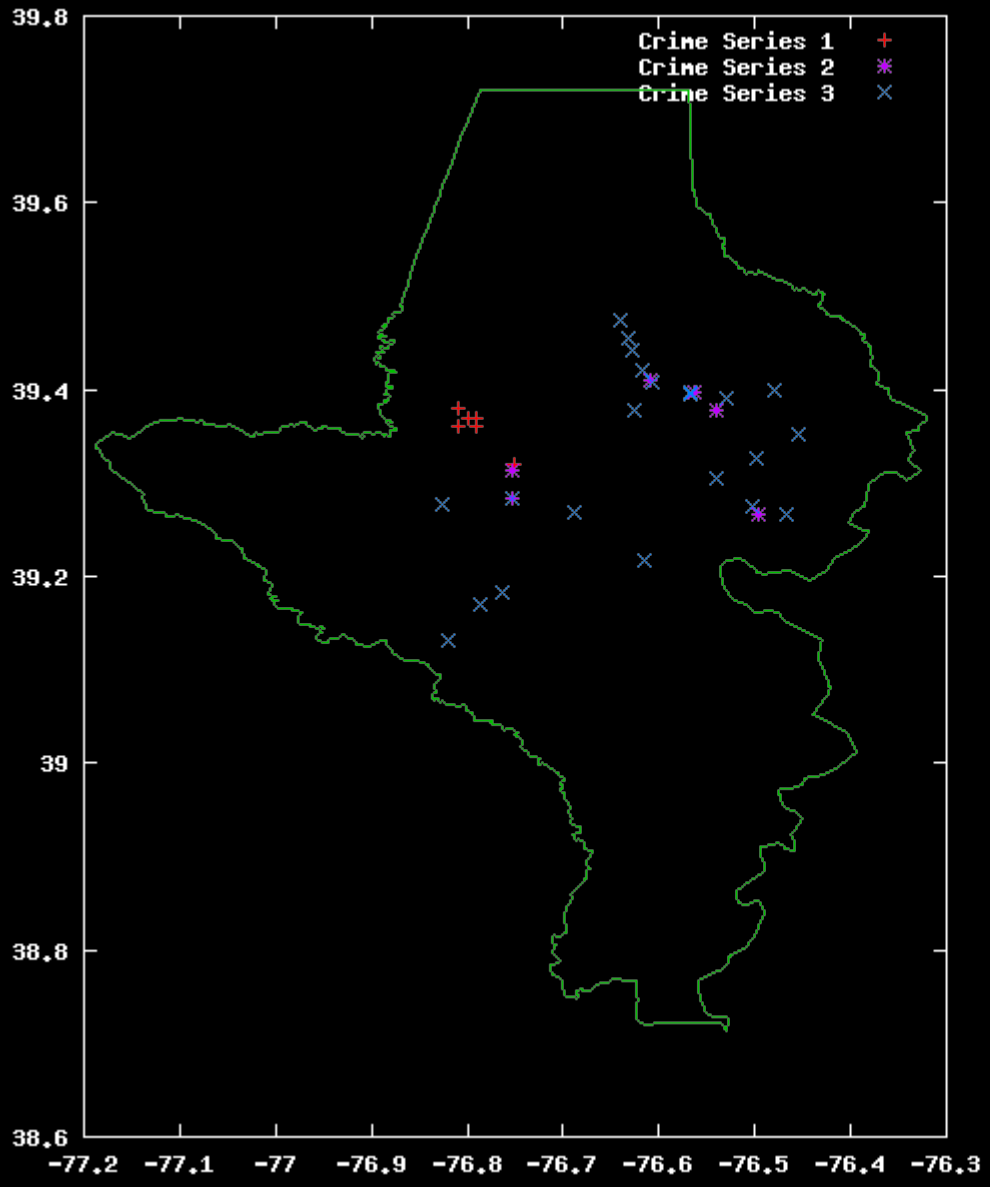
Distance Decay



Distance Decay



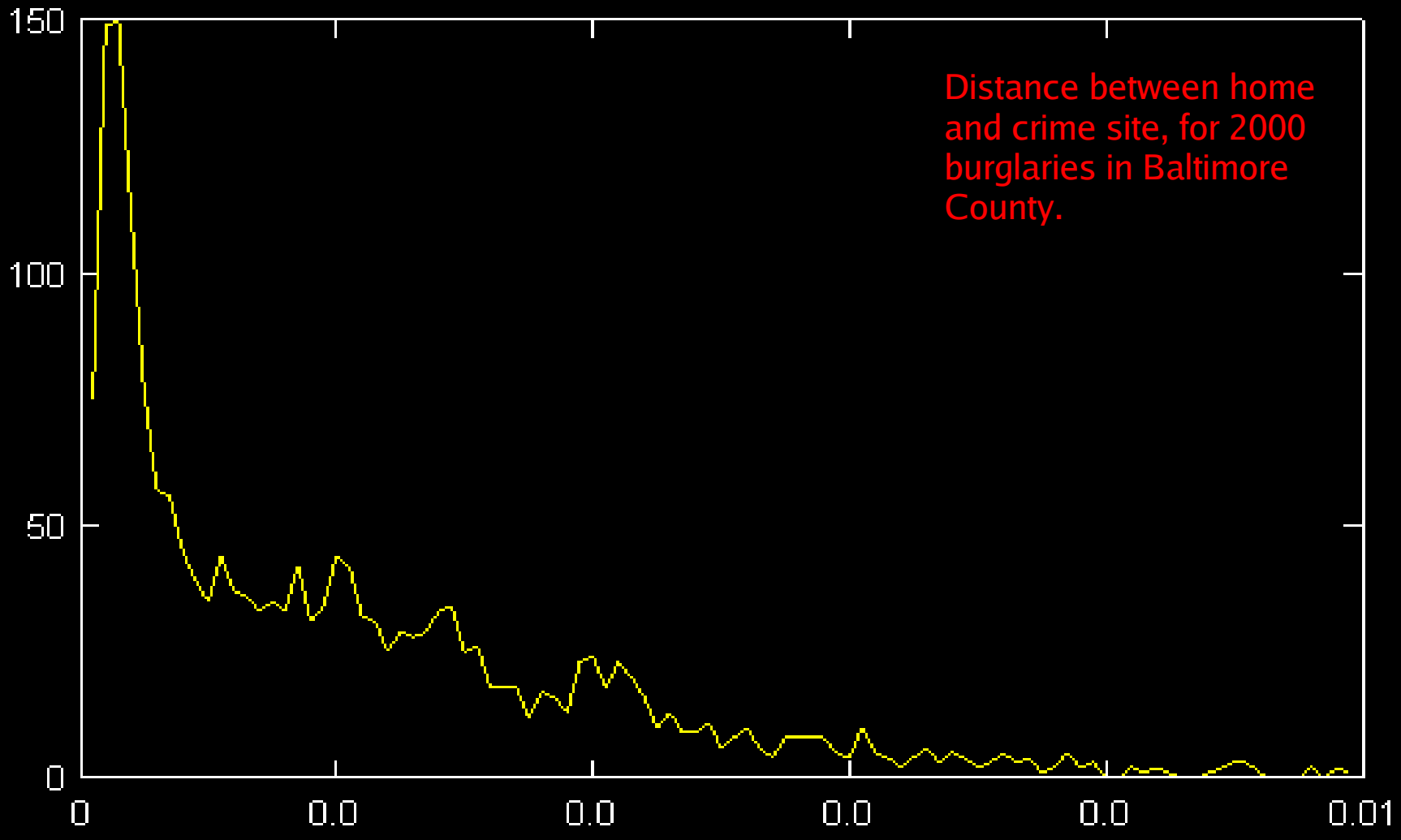
Distance Decay



Distance Decay

- Different offenders have a different average distance they will travel to their target.
  - Suppose that each offender has a decay function $f(d|\sigma)$ where σ is the average distance the offender travels.
  - Suppose the average distance an offender travels has distribution $\phi(\sigma)$.
- Then the aggregate distribution over all offenders is $$F(d) = \int_0^\infty f(d|\sigma) \cdot \phi(\sigma)\, d\sigma$$

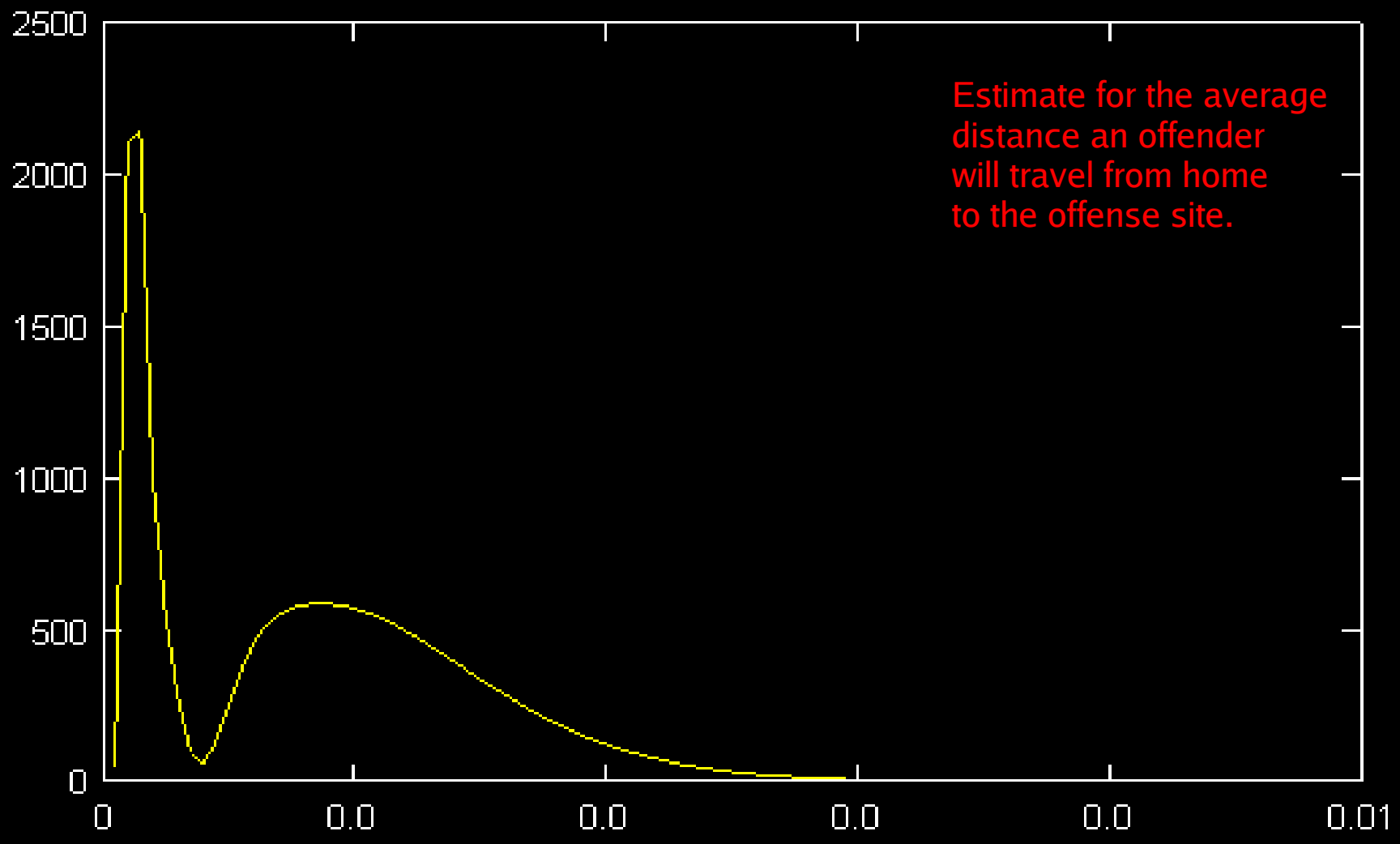
Distance Decay



Warning: Preliminary results!

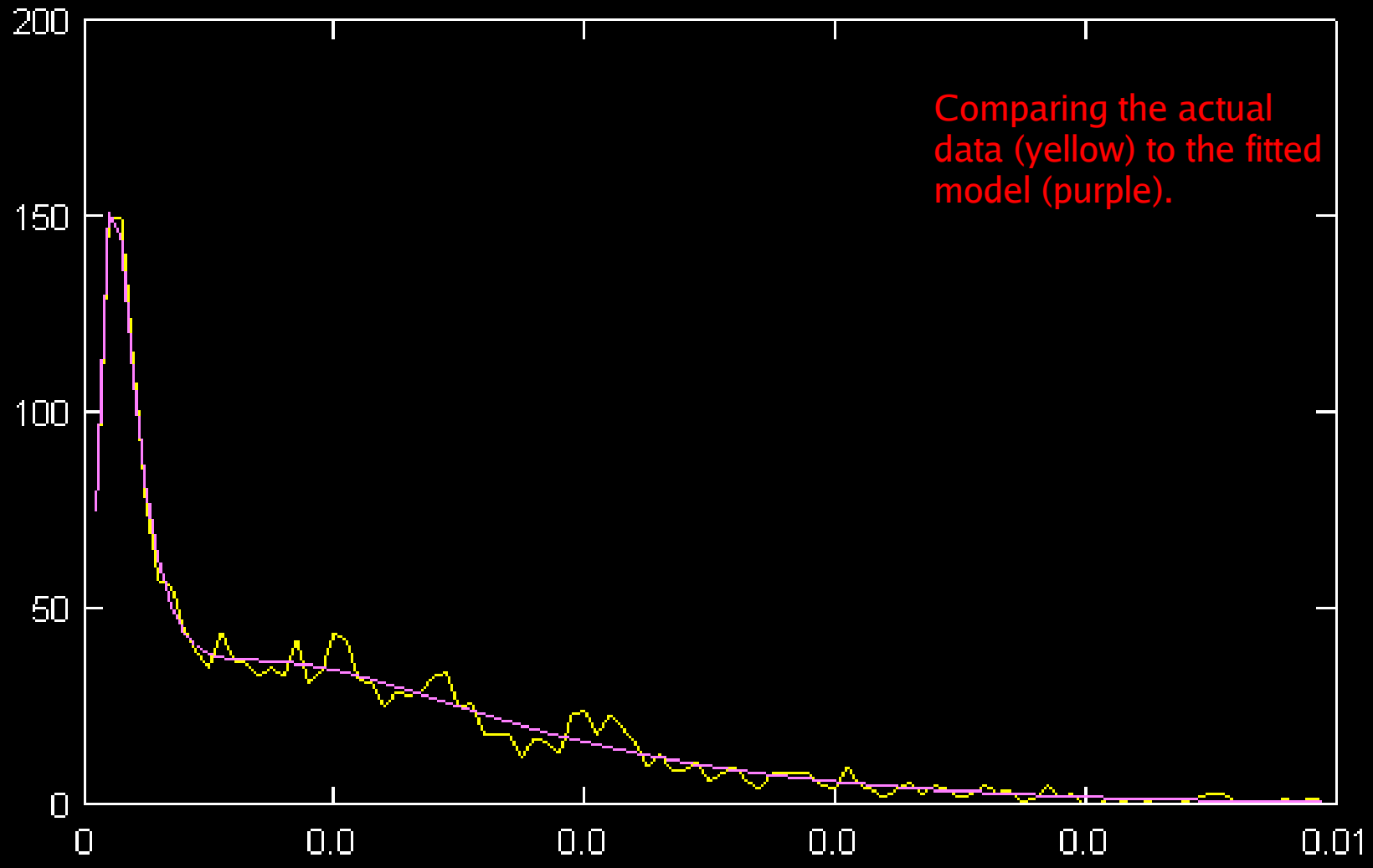
From Levine (2004)

Distance Decay



Warning: Preliminary results!

Distance Decay



Normalization

- The expression

$$P(\boldsymbol{x} \mid \boldsymbol{z}) = D(d(\boldsymbol{x}, \boldsymbol{z})) \cdot G(\boldsymbol{x}) \cdot N(z)$$

  is to represent a probability density function; as a consequence,

$$N(z) = \frac{1}{\iint_J G(y)\, D(d(y, z))\, dy^{(1)}\, dy^{(2)}}$$

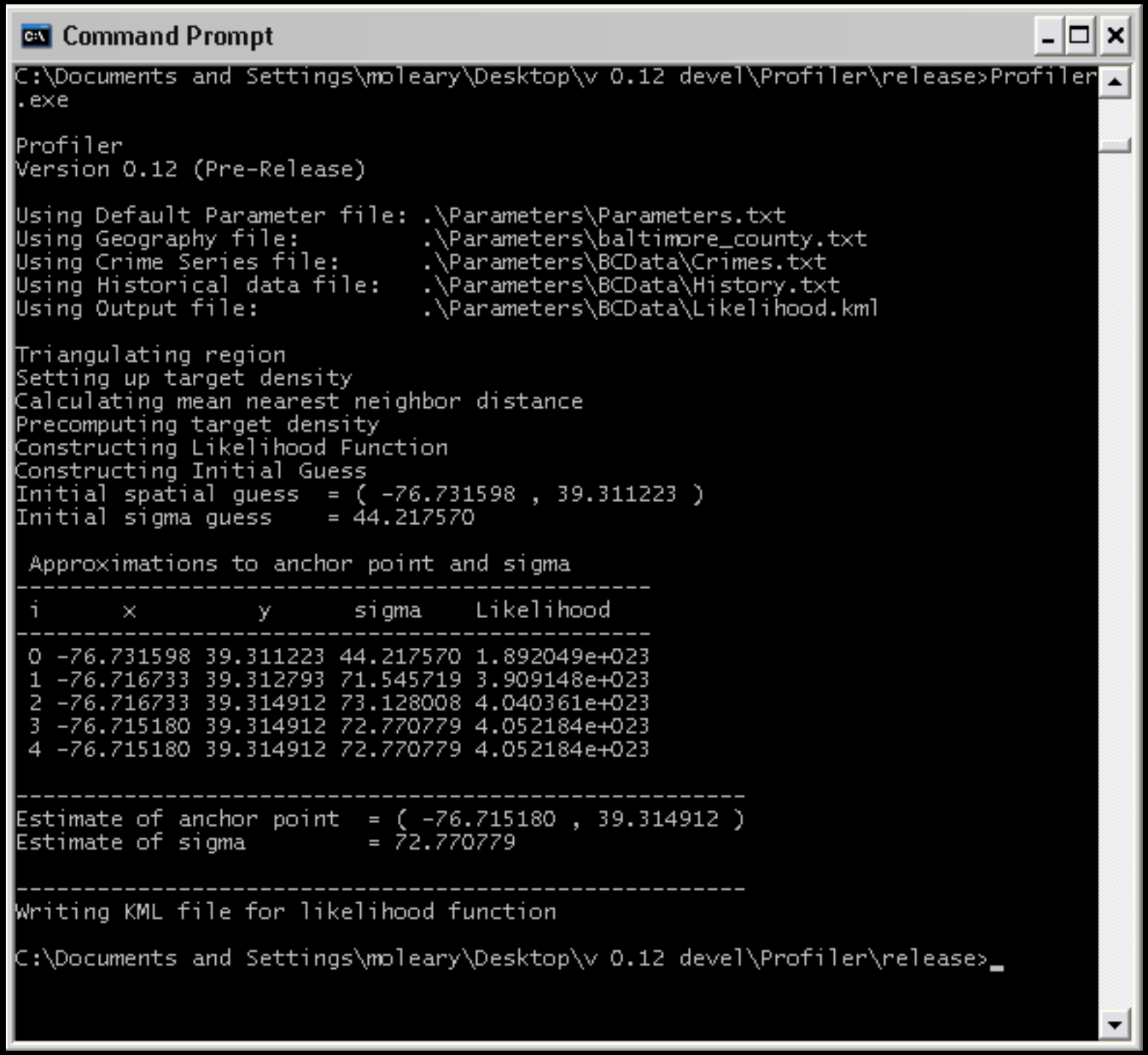
Mathematics

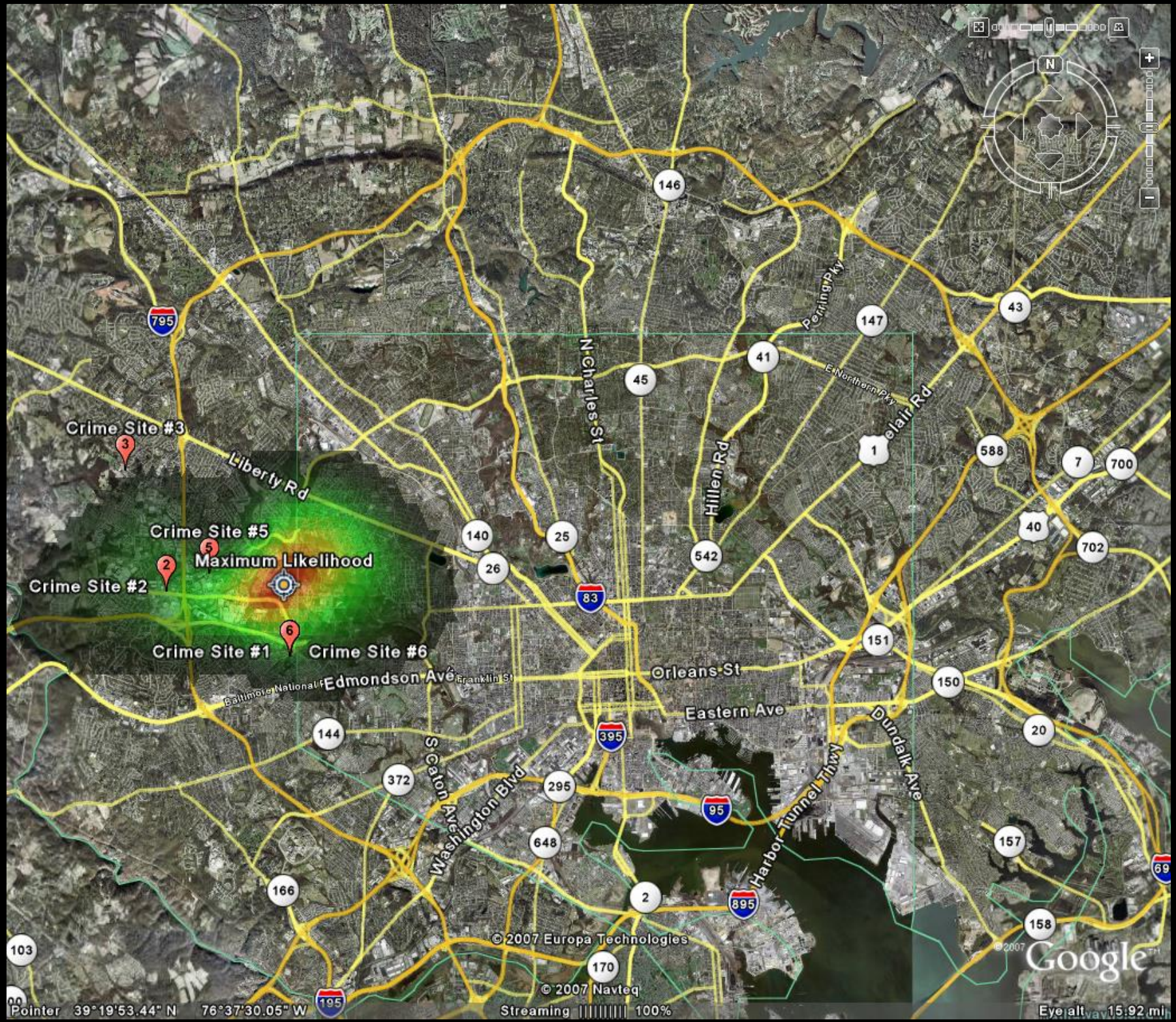
- We can estimate the offender's anchor point by calculating the *maximum likelihood estimate.*
  - We do this by finding the maximum of

$$L(y) = \frac{\prod_{i=1}^{n} D(d(x_i, y))\, G(x_i)}{\left[\iint_J D(d(\xi, y))\, G(\xi)\, d\xi^{(1)}\, d\xi^{(2)} \right]^n}$$

Implementation

- We have implemented this algorithm in software.
  - Integration was performed using a seven-point fifth-order Gaussian method.
  - Optimization was performed using a cyclic coordinate technique with a Hooke and Jeeves accelerator.
  - Running time with ~650 boundary vertices and ~1000 historical crimes is ~10 minutes.


Command Prompt
C:\Documents and Settings\moleary\Desktop\v 0.12 devel\Profiler\release>Profiler
.exe
Profiler
Version 0.12 (Pre-Release)
Using Default Parameter file: .\Parameters\Parameters.txt
Using Geography file: .\Parameters\baltimore_county.txt
Using Crime Series file: .\Parameters\BCData\Crimes.txt
Using Historical data file: .\Parameters\BCData\History.txt
Using Output file: .\Parameters\BCData\Likelihood.kml
Triangulating region
Setting up target density
Calculating mean nearest neighbor distance
Precomputing target density
Constructing Likelihood Function
Constructing Initial Guess
Initial spatial guess = (-76.731598 , 39.311223)
Initial sigma guess = 44.217570
Approximations to anchor point and sigma
i x y sigma Likelihood
0 -76.731598 39.311223 44.217570 1.892049e+023
1 -76.716733 39.312793 71.545719 3.909148e+023
2 -76.716733 39.314912 73.128008 4.040361e+023
3 -76.715180 39.314912 72.770779 4.052184e+023
4 -76.715180 39.314912 72.770779 4.052184e+023
Estimate of anchor point = (-76.715180 , 39.314912)
Estimate of sigma = 72.770779
Writing KML file for likelihood function
C:\Documents and Settings\moleary\Desktop\v 0.12 devel\Profiler\release>


Crime Site #3
Liberty Rd
Crime Site #5
Maximum Likelihood
Crime Site #2
Crime Site #1
Crime Site #6
Edmondson Ave
Franklin St
Baltimore National Pk
N Charles St
Hillen Rd
Perring Pky
E Northern Pky
Belair Rd
Orleans St
Eastern Ave
Dundalk Ave
S Caton Ave
Washington Blvd
Harbor Tunnel Thwy
© 2007 Europa Technologies
© 2007 Navteq
Google
Pointer 39°19'53.44" N 76°37'30.05" W
Streaming 100%
Eye alt 15.92 mi

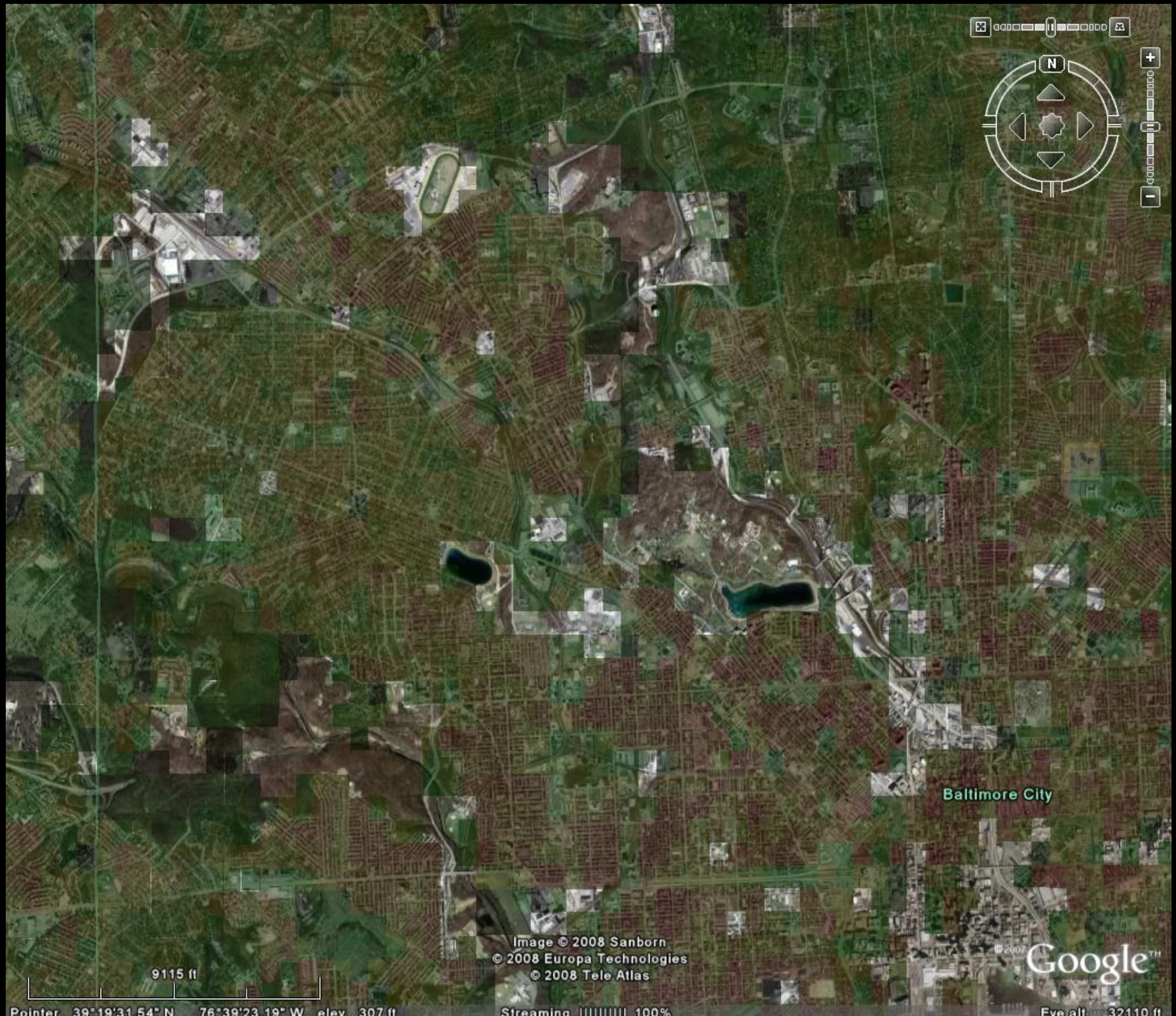
Bayesian Methods

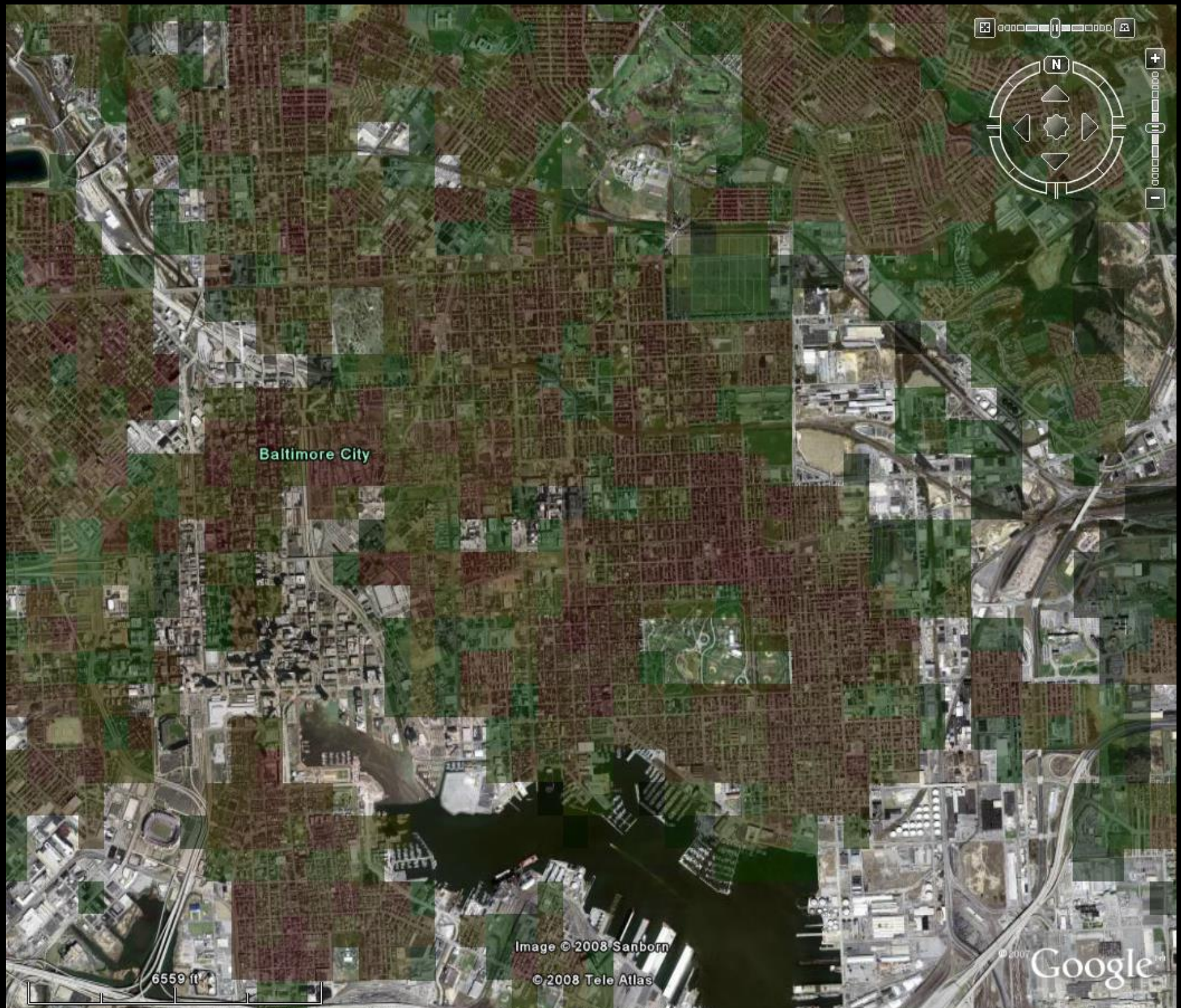
- We can get a better estimate of the search area via Bayesian methods.
  - We need a *prior* estimate for the distribution of anchor points, before the crime series is considered.
  - We also need a *prior* estimate of the average distance an offender is likely to travel.

Bayesian Methods

- To calculate the prior distribution of anchor points, we suppose that they are proportional to the local population density, and use block level census data.
  - Choose a kernel functions $K(x|\lambda)$ with bandwidth λ.
  - Let block i have center y_i, population P_i and area A_i, and set $\lambda_i = C\sqrt{A_i}$ for some constant C.
  - Then $H(z) = \sum_{i \in I} P_i K(z - y_i|\lambda_i)$

Baltimore County
Baltimore City
Reed Bird Island
Hathaway Island (historical)
© 2008 Europa Technologies
© 2008 Tele Atlas
Google
5.69 mi
Pointer 39°21'03.47" N 76°37'32.54" W elev 299 ft
Streaming 100%
Eye alt 19.79 mi


N
Baltimore City
Image © 2008 Sanborn
© 2008 Europa Technologies
© 2008 Tele Atlas
9115 ft
Google™


Baltimore City
Image © 2008 Sanborn
© 2008 Tele Atlas
6559 ft
Google

Baltimore County
2.35 mi
© 2008 Tele Atlas
©2007 Google™
Pointer 39°25'22.33" N 76°37'31.14" W elev 371 ft
Streaming 100%
Eye alt 43510 ft

Bayesian Methods

- If we have n crimes, and we assume that the crime locations are all independent then

$$P(z|x_1, x_2, \cdots, x_n)$$

$$\propto \int_0^\infty \prod_{i=1}^n P(x_i|z, \sigma) H(z) \pi(\sigma)\, d\sigma$$

$$\propto \int_0^\infty \prod_{i=1}^n D(d(x_i, z), \sigma) G(x_i)$$

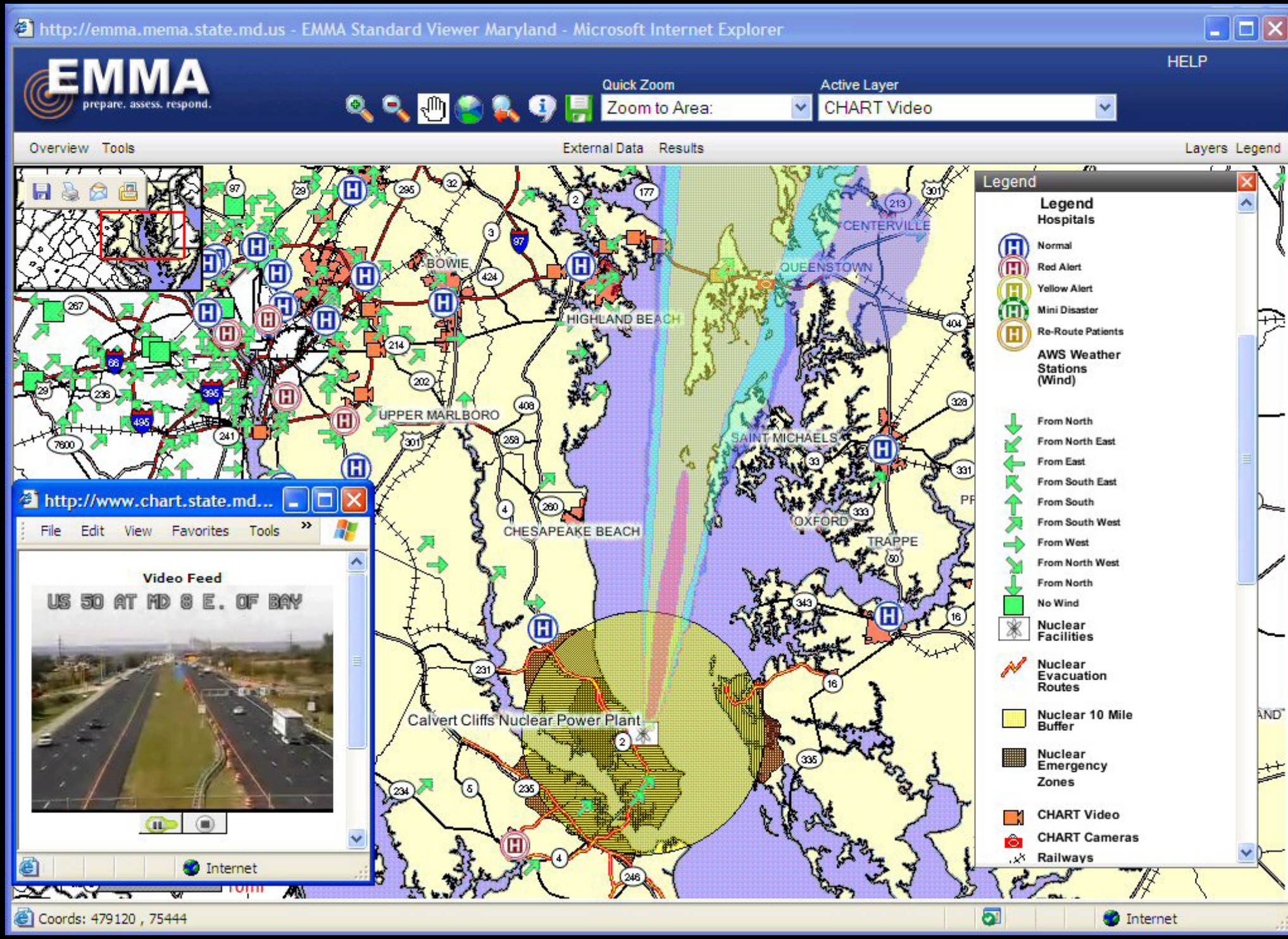
$$\cdot N(z) H(z) \pi(\sigma)\, d\sigma$$

Implementation

- Code to implement these techniques is under development.
  - Estimated completion dates:
    - First draft: late May
    - Complete: late August.

Operational Questions

- A good decision support system should not require that the end user be a content expert.
  - Our software is being developed with ease of use uppermost in mind.


http://emma.mema.state.md.us - EMMA Standard Viewer Maryland - Microsoft Internet Explorer
EMMA
prepare. assess. respond.
HELP
Quick Zoom
Zoom to Area:
Active Layer
CHART Video
Overview Tools
External Data Results
Layers Legend
Legend
Legend
Hospitals
Normal
Red Alert
Yellow Alert
Mini Disaster
Re-Route Patients
AWS Weather Stations (Wind)
From North
From North East
From East
From South East
From South
From South West
From West
From North West
From North
No Wind
Nuclear Facilities
Nuclear Evacuation Routes
Nuclear 10 Mile Buffer
Nuclear Emergency Zones
CHART Video
CHART Cameras
Railways
http://www.chart.state.md...
File Edit View Favorites Tools
Video Feed
US 50 AT MD 8 E. OF BAY
Internet
BOWIE
HIGHLAND BEACH
UPPER MARLBORO
CHESAPEAKE BEACH
CENTERVILLE
QUEENSTOWN
SAINT MICHAELS
OXFORD
TRAPPE
Calvert Cliffs Nuclear Power Plant
Coords: 479120 , 75444
Internet

Strengths

- This approach meets all of our requirements for a good geographic profiling technique.
  - All of the assumptions on criminal behavior are made in the open.
  - They can be challenged, tested, discussed and compared.

Weaknesses of this Framework

- GIGO
  - The method is only as accurate as the accuracy of the choice of $P(\boldsymbol{x} \mid \boldsymbol{z})$
- It is unclear what the right choice is for $P(\boldsymbol{x} \mid \boldsymbol{z})$
  - Even with the simplifying assumption that

$$P(\boldsymbol{x} \mid \boldsymbol{z}) = D(d(\boldsymbol{x}, \boldsymbol{z})) \cdot G(\boldsymbol{x}) \cdot N(z)$$

    this is difficult.

Weaknesses

- The framework assumes that crime sites are independent, identically distributed random variables.
  - This is probably false in general!
- This should be a solvable problem though...

Next Steps

- Model improvements:
  - What would a better choice for the model of criminal behavior?
- Model selection and multi-model inference.

Questions?

Contact information:

Dr. Mike O'Leary

Director, Center for Applied Information Technology

Towson University

Towson, MD 21252

410-704-7457

moleary@towson.edu