Crime Analytics and Multiagent Crime Simulation: Concepts and Applications

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FUNDAÇÃO EDSON QUEIROZ
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ENSINANDO E APRENDENDO

Agenda

- Basic Concepts
- Multiagent Crime Simulation
  - Teaching Police Allocation
  - Checking Stylized facts
  - Preventive Police
  - Reactive Police
- Crime and Human Movement
- Conclusion

What is “simulation”?

“A model is a simplification (smaller, less detailed, less complex, or all of these together) of some other structure or system”

Gilbert, N and Troitszch, K: 1999, Simulation for the Social Scientist, Open University Press, Philadelphia

Simulation + complexity

Simple systems… can be modelled mathematically, but…

"when matters get a little more complex… the system is studied by carrying out **simulations** for various values of the parameters"

Simon, HA: 1995, Artificial Intelligence: an Empirical Science, Artificial Intelligence, 77, 95-127

Simulation + science

Simulation… “is a **third way** of doing science. Whereas the purpose of induction is to **find patterns** in data and that of deduction is to **find consequences** of assumptions, the purpose of agent-based modelling is **to aid intuition**”

Axelrod, R.: 1997, Advancing the art of simulation in the social sciences, in Conte, R., Hegselmann, R. and Terna, P. (eds), Simulating Social Phenomena, pp. 21-40, Springer, Berlin

Simulation + mathematics

"Simulation is necessary because the interactions of adaptive agents typically lead to nonlinear effects that are not amenable to the deductive tools of formal mathematics"

Axelrod, R.: 1997, Advancing the art of simulation in the social sciences, in Conte, R., Hegselmann, R. and Terna, P. (eds), Simulating Social Phenomena, pp. 21-40, Springer, Berlin

Simulation + prediction

"The main purpose of agent-based models is **not prediction** but a deeper **understanding** of how fundamental social processes operate"

Axelrod, R.: 1997, Advancing the art of simulation in the social sciences, in Conte, R., Hegselmann, R. and Terna, P. (eds), Simulating Social Phenomena, pp. 21-40, Springer, Berlin

In Summary: Why Multiagent in Social Science

The interaction of simple multiple agents leads the emergence of complex non-linear behavior helping the understanding of the social phenomena

Multiagent Crime Simulation(MACS)

Theory and Stylized Facts

Routine Active Theory (Cohen and Felson, 1979)
Repeat Victimization
Hot Spot Formation
Environmental Criminology (Brantingham and Brantingham, 1991)
Ambient Population (Malleson and Andresen, 2015)

Agents

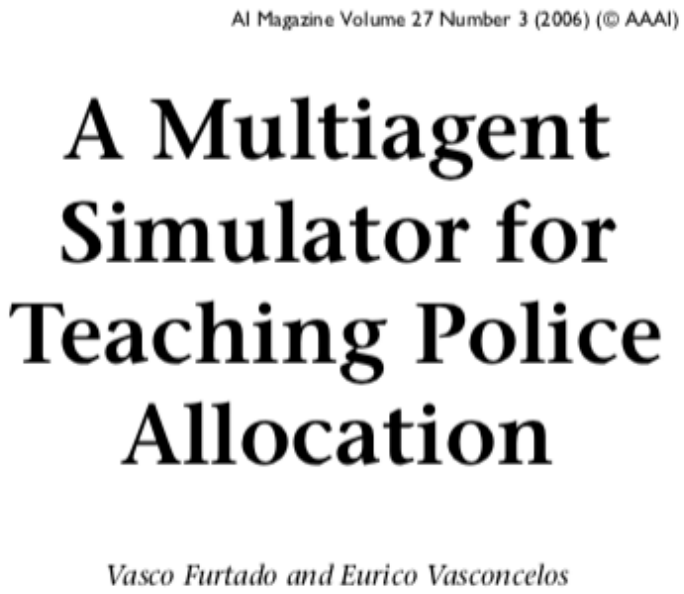
Criminals
Guardians
Targets
Environment

MACS and Data Analytics

- **Uncovering Stylized Facts**
- **Data as input to MACS**
- **Validation of Real Case Scenarios**

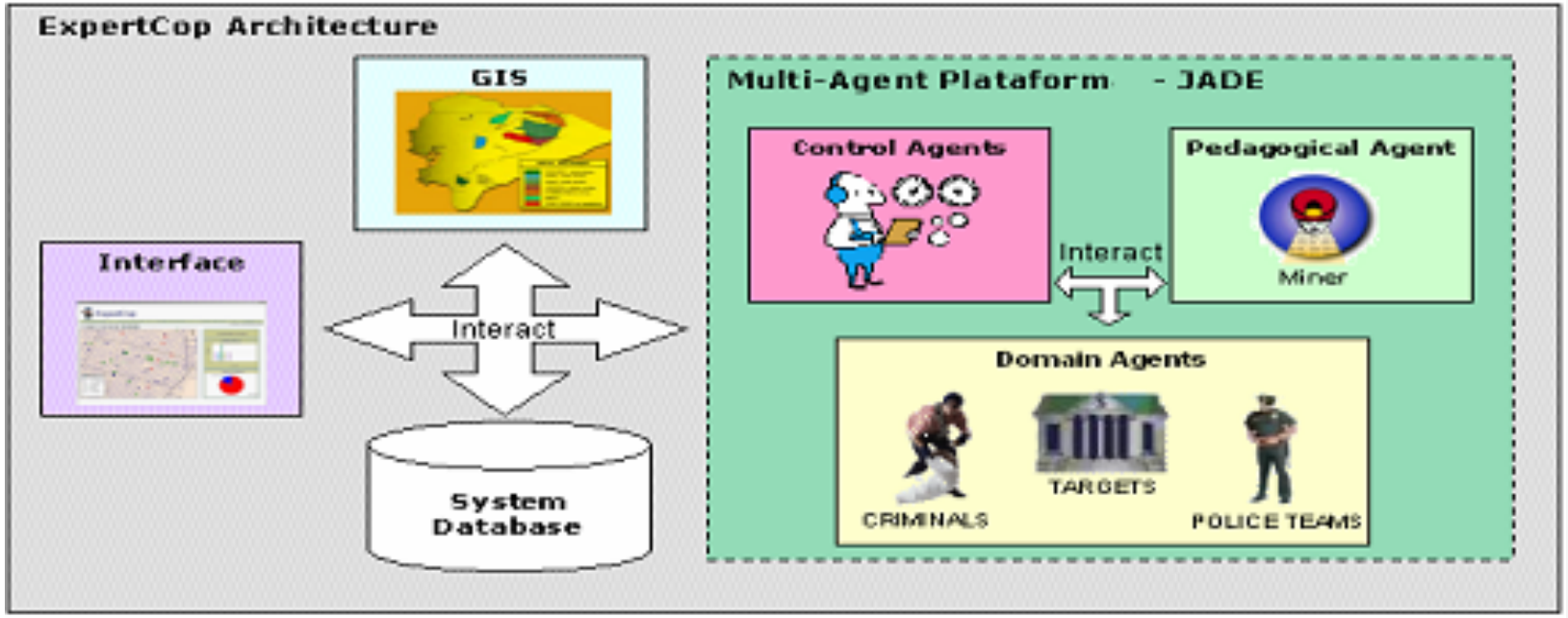
Applications and Examples

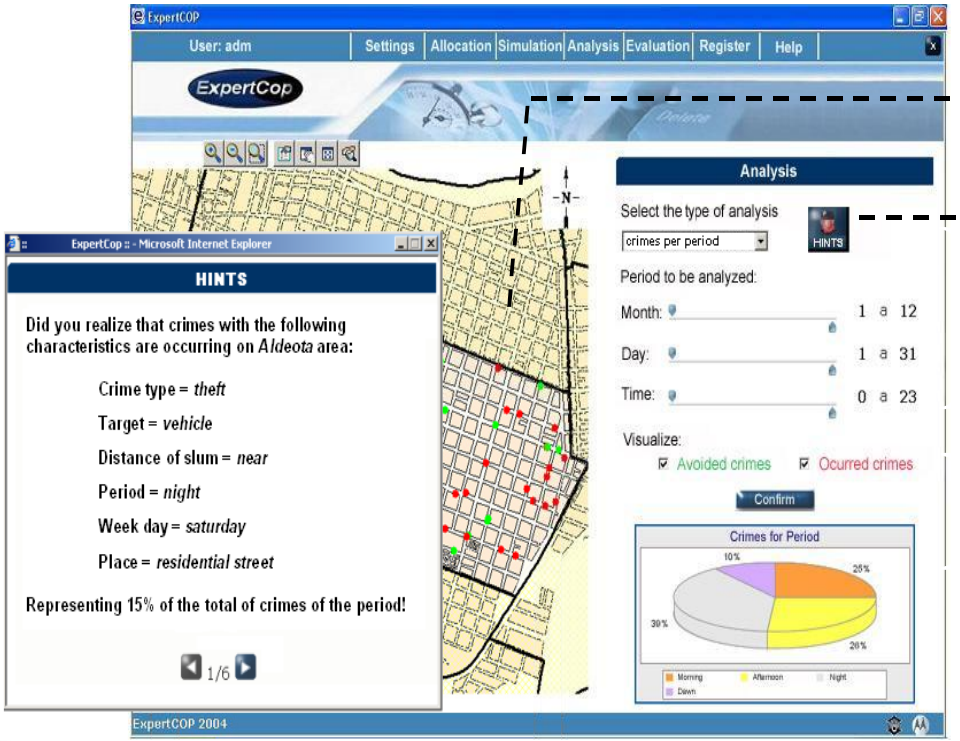
Intelligent Tutoring



ExpertCop is a software that enables police officers to better allocate the preventive police force in the urban areas. It produces, based on a police resource allocation plan, simulations of how crime behaves in a certain period of time based on the defined allocation. The goal is to allow a critical analysis by police officers who use the system, making them understand the cause-and-effect relation of their decisions

ExpertCOP


ExpertCop Architecture
GIS
Interface
Interact
System Database
Multi-Agent Plataform - JADE
Control Agents
Pedagogical Agent
Miner
Interact
Domain Agents
TARGETS
CRIMINALS
POLICE TEAMS



Map with the simulation results crimes occurred and avoide filtered by the user selections.

Hint button.

Functionalities for selection of the type of graphic and the crimes by period (month, day, time).

Graphic about the selected results.

Results

Minister of the Justice hired the ExpertCop team for giving three classes using ExpertCop for police officers of different states

- 87% of students changed or included new beliefs about motives and causes of crime.
- In the evaluation, beliefs that were more specific and practical replaced those initially observed, which were more generic.
- New beliefs about specific factors such as public illumination, patrol route distances, the existence of slums, and work shifts, were included by the students in the second collection.
- Time factors, such as the relationship between the day and the periods of the day, with the number of crimes occurred, began to be taken into consideration.
- Many beliefs were mentioned related to the importance of the analysis of the characteristics of the geographical area for good policing.

ARTICLE

Analyzing police patrol routes by simulating the physical reorganization of agents

Authors: Adriano Melo, Mairon Belchior, Vasco Furtado Authors Info & Affiliations

Publication: MABS'05: Proceedings of the 6th international conference on Multi-Agent-Based Simulation • July 2005 • Pages 99–114 • https://doi.org/10.1007/11734680_8

Hierarchical and Centralized Command

The commander knows:

i) How much crime a patrol has avoided.

ii) The target more vulnerable.

Should a patrol be reallocated ?

Optimizing Police Patrol Routes

International Conference on Intelligence and Security Informatics

ISI 2006: Intelligence and Security Informatics pp 485-491 | Cite as

Towards Optimal Police Patrol Routes with Genetic Algorithms

Authors | Authors and affiliations

Chapter

from book Advances in Artificial Intelligence - IBERAMIA-SBIA 2006, 2nd International Joint Conference, 10th Ibero-American Conference on AI, 18th Brazilian AI Symposium, Ribeirão Preto, Brazil, October 23-27, 2006, Proceedings (pp.118-127)

GAPatrol: An Evolutionary Multiagent Approach for the Automatic Definition of Hotspots and Patrol Routes

Conference Paper · January 2006 *with* 151 Reads

DOI: 10.1007/11874850_16
Issn: 0302-9743

Cite this publication

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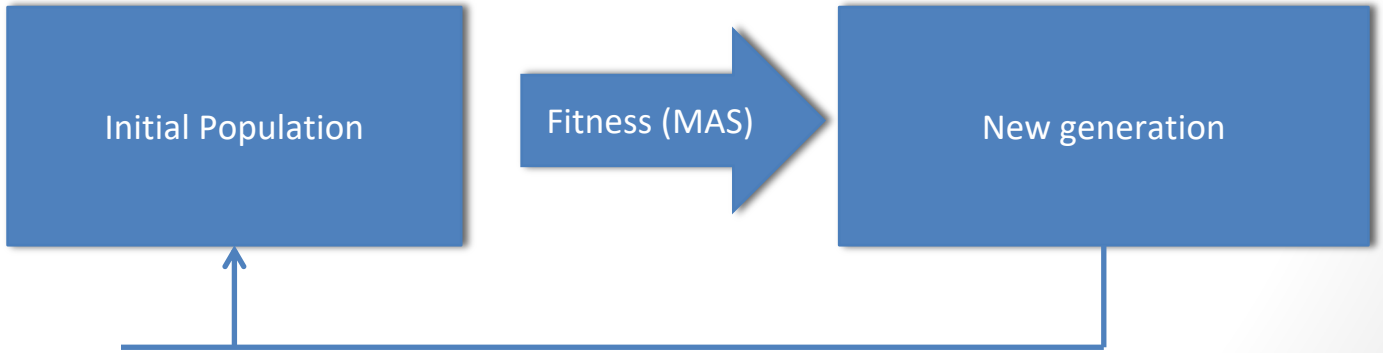
Vasco Furtado
27.03 · Universidade de Fortaleza

The Approach: Overview

- An evolutionary algorithm searches for the best function that minimizes crime
- The fitness function is a multi-agent simulator (MAS) that implements



2. GAPatrol evolutionary process: decreasing in fitness due to hotspots discovery

One aspect investigated here relates to the GAPatrol's facility to automatically discover crime hotspots, that is, high crime density regions (or targets) that deserve to be better covered by the routine patrol surveillance.

Crime Model Simulation

ELSEVIER

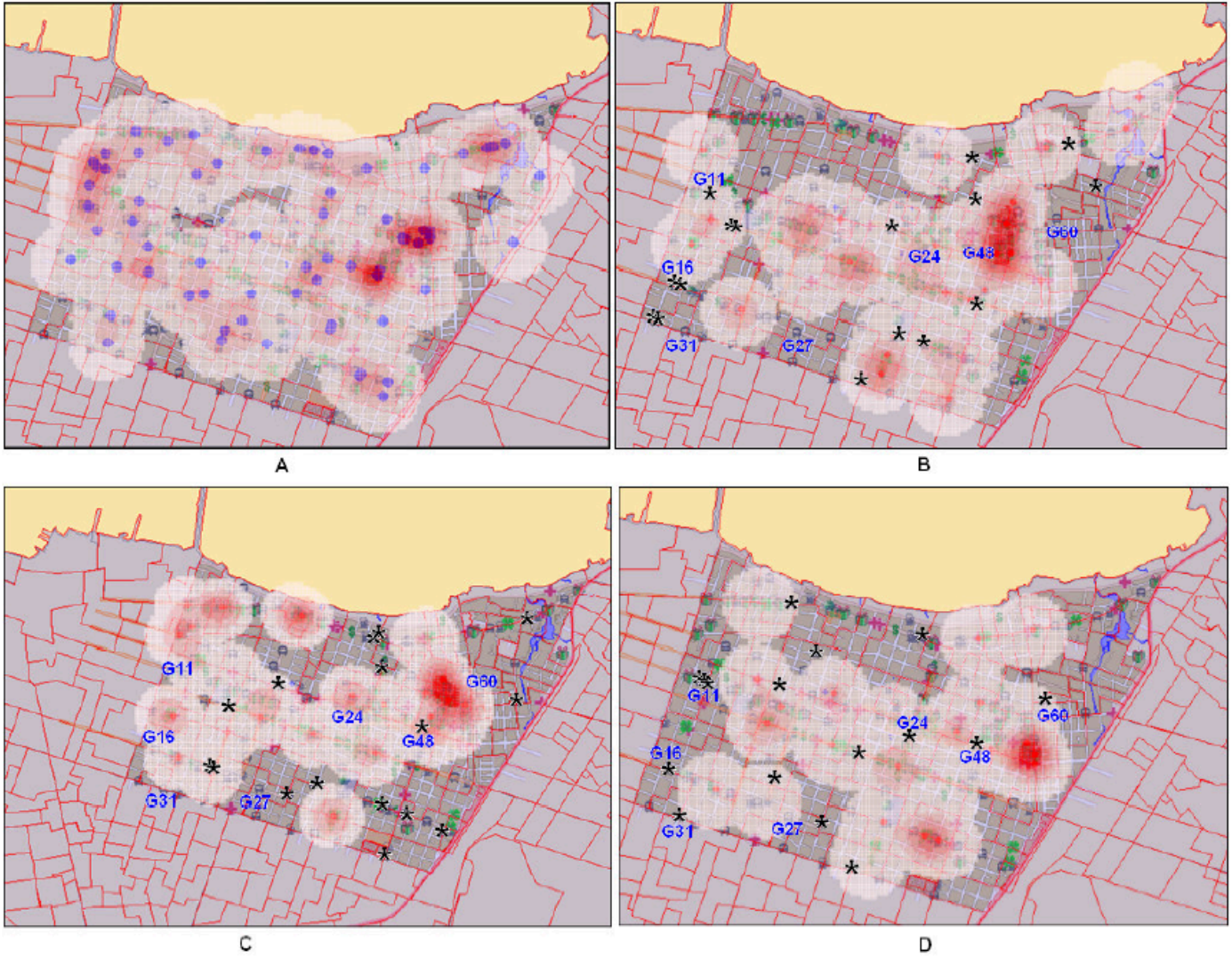
Decision Support Systems
Volume 48, Issue 1, December 2009, Pages 282-292

A bio-inspired crime simulation model

Vasco Furtado [a], Adriano Melo [a], André L.V. Coelho [a], Ronaldo Menezes [b], Ricardo Perrone [c]

Modeling the criminal behavior and the social relation between them

Innovative approach: using ant colony organization to mimic the social aspect and the use of genetic algorithm to tuning the model (the concept of gateways)


A
B
G11
G16
G31
G27
G24
G48
G60
C
D

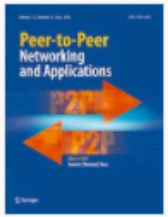
Reactive Police

Conferences > 2015 IEEE International Confe...

Multi-objective evolutionary algorithms and multiagent models for optimizing police dispatch

Publisher: IEEE

3 Author(s) Ricardo Guedes ; Vasco Furtado ; Tarcísio Pequeno **View All Authors**



Peer-to-Peer Networking and Applications
July 2019, Volume 12, Issue 4, pp 865–880 | Cite as

Pareto set as a model for dispatching resources in emergency Centres

Authors Authors and affiliations

Ricardo Guedes, Vasco Furtado ✉, Tarcísio Pequeno, Joel J. P. C. Rodrigues

The Dispatch Task

- A set of calls for assistance characterized by features describing the type of the occurrence
- A set of available resources
- A policy for attending the calls. Typically If there is no resource available, the call enters a queue and wait for attendance
- Goal: To answer the calls following a policy and reaching a global “good quality” (e.g. minimizing the waiting time)

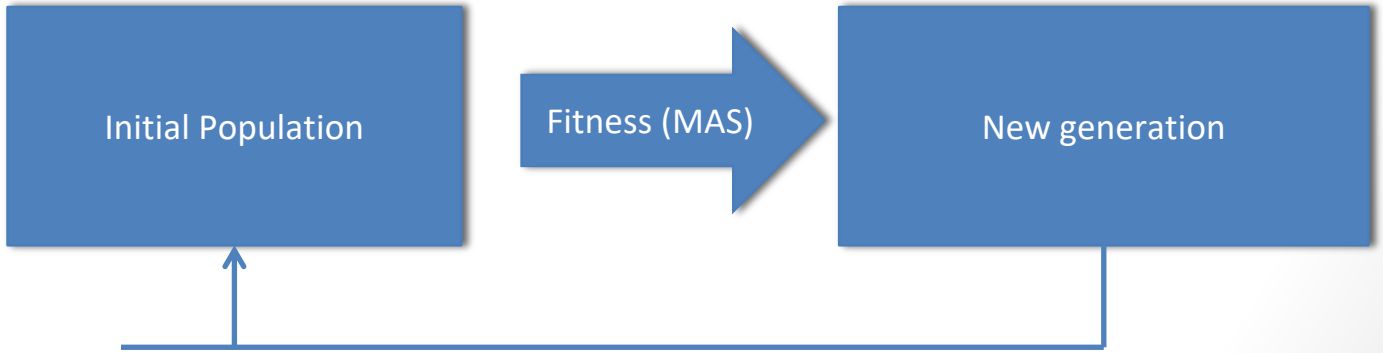
Dispatch Policies

- *First-come first-served* (FCFS) – Waiting time (sense of fairness)
- *Shortest job first (SJF) with/without aging – Waiting time*
- *Priority-based dispatching with/without aging – Priority calls*
- *Nearest occurrence – cost*
- These strategies seek to optimize the attendance of occurrences considering only one goal
- *Previous work have shown that SJF minimizes waiting time but can lead to starvation of priority calls*

- Motivation
  - *What is the best policy considering the conflicting/competing goals altogether ?*

The Approach: Overview

- An evolutionary algorithm searches for the best ranking function
- Multi-objective evolutionary algorithm cope with the competing/conflicting dimensions
- The fitness function is a multi-agent simulator (MAS) that implements

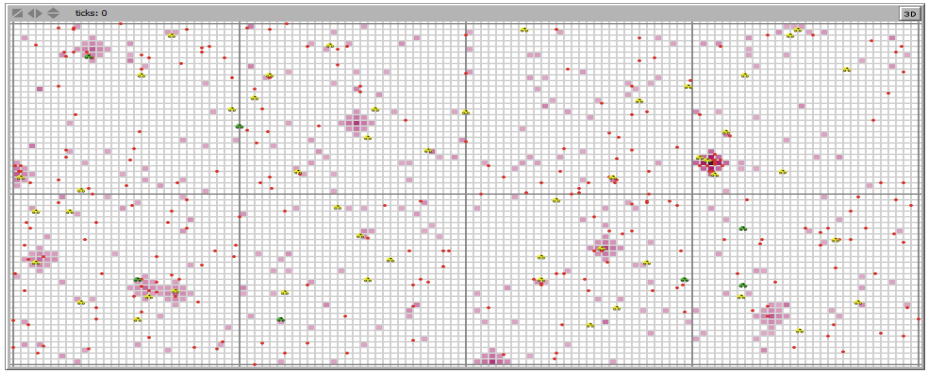


Characterization of the calls

- **A synthetic workload was generated based on a real workload from 220 thousand actual crime events reported in the year of 2001 in a large Brazilian city:**
- **event arrival process is Poisson in all 24 districts of the analyzed city and for each individual crime type considered, during periods of stable arrival rate**
- **crime event attendance time is exponentially distributed for each crime type in each city district**
- **spatial crime distribution follows a Power Law (PL) Distribution.**
- **Different types of occurrences exist. In our simulations we group them in four: administrative procedures, violent crimes, assistance calls, and others**
- **Calls appear in specific locations of the environment (according to a PL)**

The Environment

- Police patrol in cars are agents that move around the environment.
- Available cars are asked to move to the place of the occurrence
- The simulation environment is a grid of 7,200 cells
- These cells form eight districts

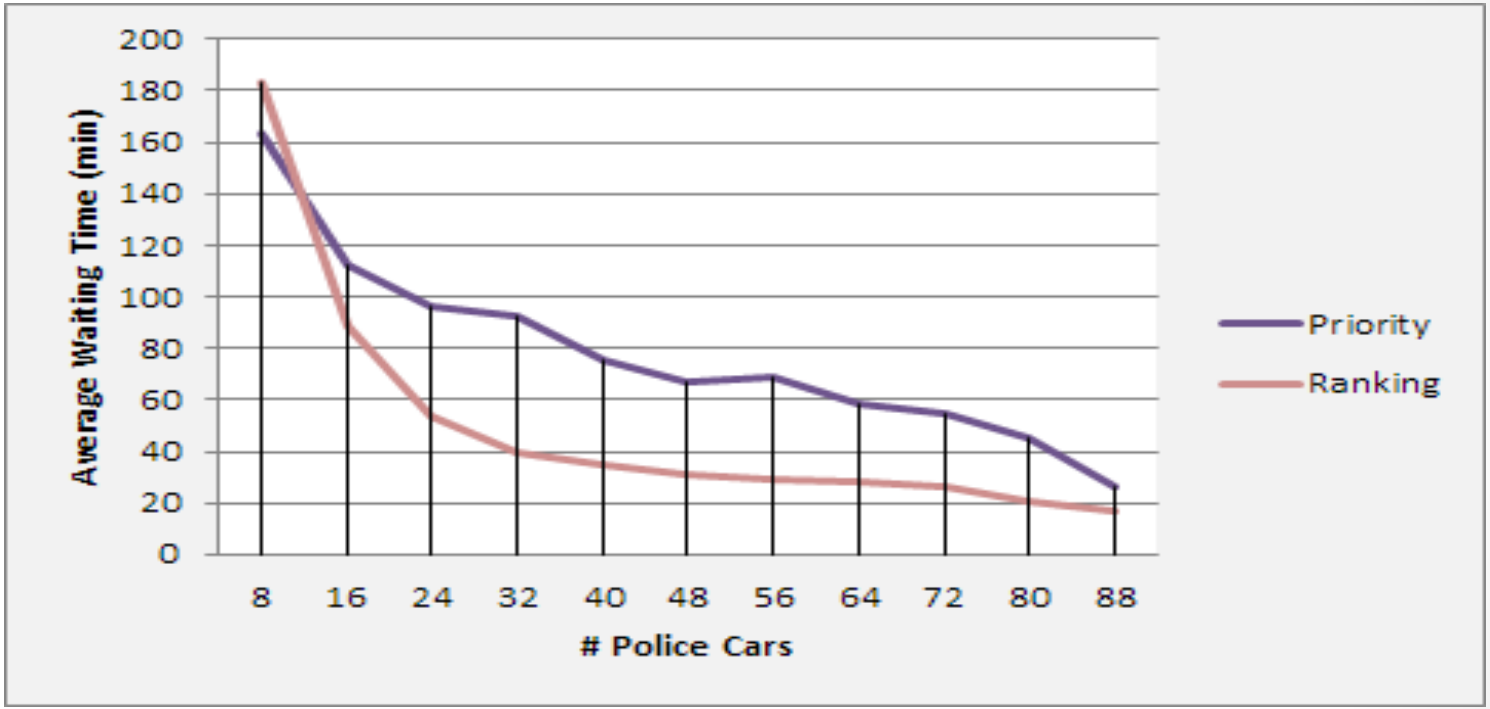


Comparative results from simulations of eight different strategies of dispatch

For the solution x = (*dw=10,pw=-9,tw=-8,ow=-9*)

	Random	FCFS	Priority	Priority / Aging	SJF	SJF / Aging	Nearest	Ranking
% Attendance of calls	67.4	69.7	54.3	55	77.8	79.9	89.3	78.9
% Attendance of priority calls	69.4	66.8	100	100	0.2	4.7	88.2	99.5
Distance traveled (km)	289.7	291.4	236	236.3	340.3	335.3	74.6	157.5
Waiting time in queue (min)	145.4	339.3	59.2	164.4	32.6	297.6	97.3	20

Average waiting time: Ranking versus Priority



- The Ranking strategy outperforms the Priority strategy converging to the same delay of attendance while the resources available increases

Percentage of attendance of calls

RESULTS

- The "Ranking" strategy has the best waiting time, serves almost 100% of priority calls, it is the second most economic and it is the third in attendance of calls
- That is to say, it is a strategy in which the four dimensions are considered without major prejudice for any of them

Human Mobility as Proxy for Crime: Towards a Quantitative Approach for the Routine Activity Theory

City Dynamics via Social Relationship

- Direct Relationship
  - Interactions between people
- Indirect Relationship
  - Spatial-temporal convergence in public spaces (e.g. Parks, beaches, buses, buildings)

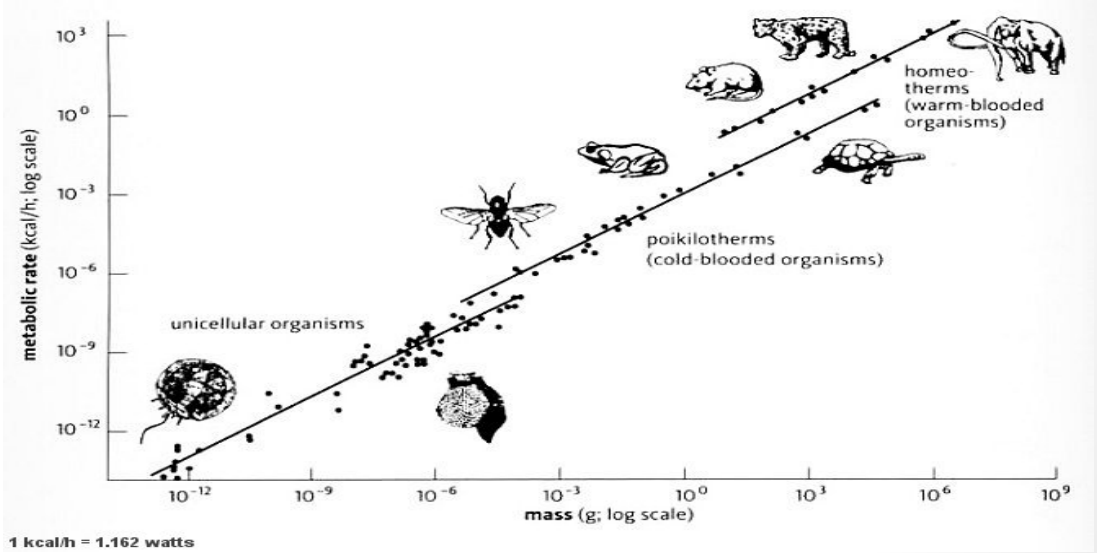
Impact in Crime

- Research in Criminology/Sociology
  - Routine Activity Theory
  - Repeat Victimization
  - Journey to Crime
  - Broken Window Theory
  - Environmental Criminology

Allometry

- Born in biology
  - Kleiber's Law (β = 3/4) mass scales ¾ power of metabolic rate

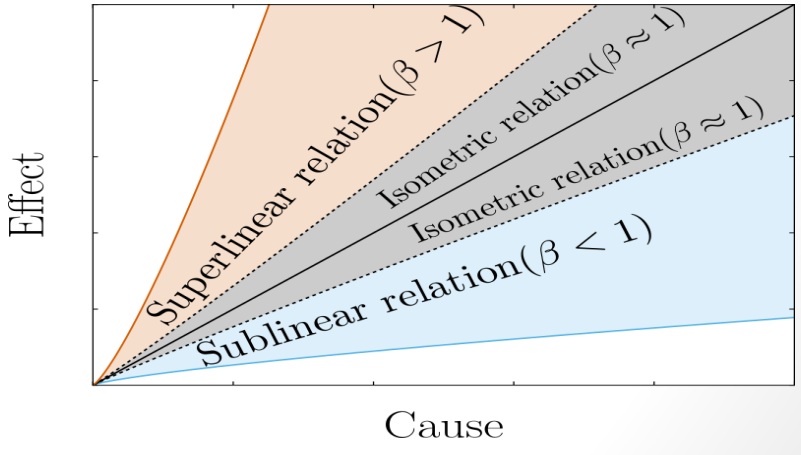
$$Y = aX^{\beta},$$



Allometry in the Social Context

	Biology	Sociology
	Living organisms	Cities (Urban agglomerates)
Dimension (cause)	Mass	Population
Feature (effect)	Biological feature (Metabolic rate, size of a member)	Urban or environmental indicator (Number of crimes, gas emissions)

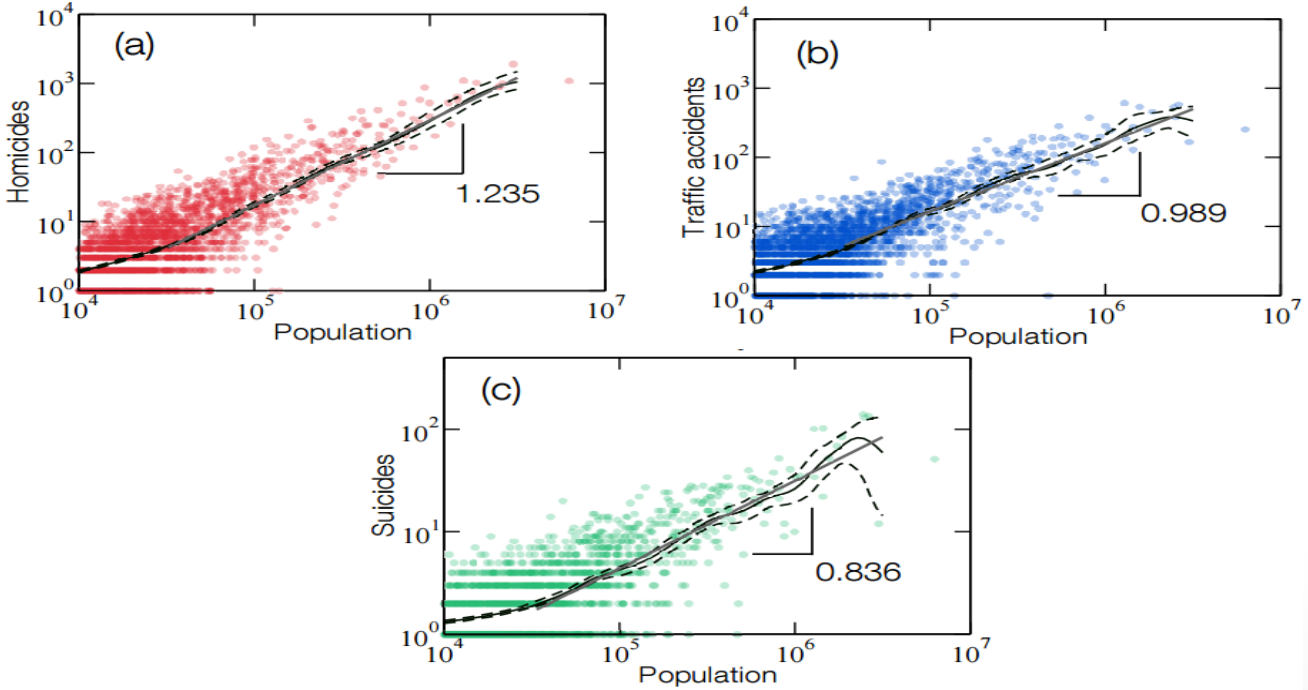
$$Y = aX^{\beta},$$



Bettencourt *et al* (2007)

Y	β	95% CI	Adj-R^2	Observations	Country–year
New patents	1.27	[1.25,1.29]	0.72	331	U.S. 2001
Inventors	1.25	[1.22,1.27]	0.76	331	U.S. 2001
Private R&D employment	1.34	[1.29,1.39]	0.92	266	U.S. 2002
"Supercreative" employment	1.15	[1.11,1.18]	0.89	287	U.S. 2003
R&D establishments	1.19	[1.14,1.22]	0.77	287	U.S. 1997
R&D employment	1.26	[1.18,1.43]	0.93	295	China 2002
Total wages	1.12	[1.09,1.13]	0.96	361	U.S. 2002
Total bank deposits	1.08	[1.03,1.11]	0.91	267	U.S. 1996
GDP	1.15	[1.06,1.23]	0.96	295	China 2002
GDP	1.26	[1.09,1.46]	0.64	196	EU 1999–2003
GDP	1.13	[1.03,1.23]	0.94	37	Germany 2003
Total electrical consumption	1.07	[1.03,1.11]	0.88	392	Germany 2002
New AIDS cases	1.23	[1.18,1.29]	0.76	93	U.S. 2002–2003
Serious crimes	1.16	[1.11, 1.18]	0.89	287	U.S. 2003
Total housing	1.00	[0.99,1.01]	0.99	316	U.S. 1990
Total employment	1.01	[0.99,1.02]	0.98	331	U.S. 2001
Household electrical consumption	1.00	[0.94,1.06]	0.88	377	Germany 2002
Household electrical consumption	1.05	[0.89,1.22]	0.91	295	China 2002
Household water consumption	1.01	[0.89,1.11]	0.96	295	China 2002
Gasoline stations	0.77	[0.74,0.81]	0.93	318	U.S. 2001
Gasoline sales	0.79	[0.73,0.80]	0.94	318	U.S. 2001
Length of electrical cables	0.87	[0.82,0.92]	0.75	380	Germany 2002
Road surface	0.83	[0.74,0.92]	0.87	29	Germany 2002

Melo *et al* (2014)



Statistical signs of social influence on suicides Scientific reports 4 (2014): 6239.

Allometry and Crime

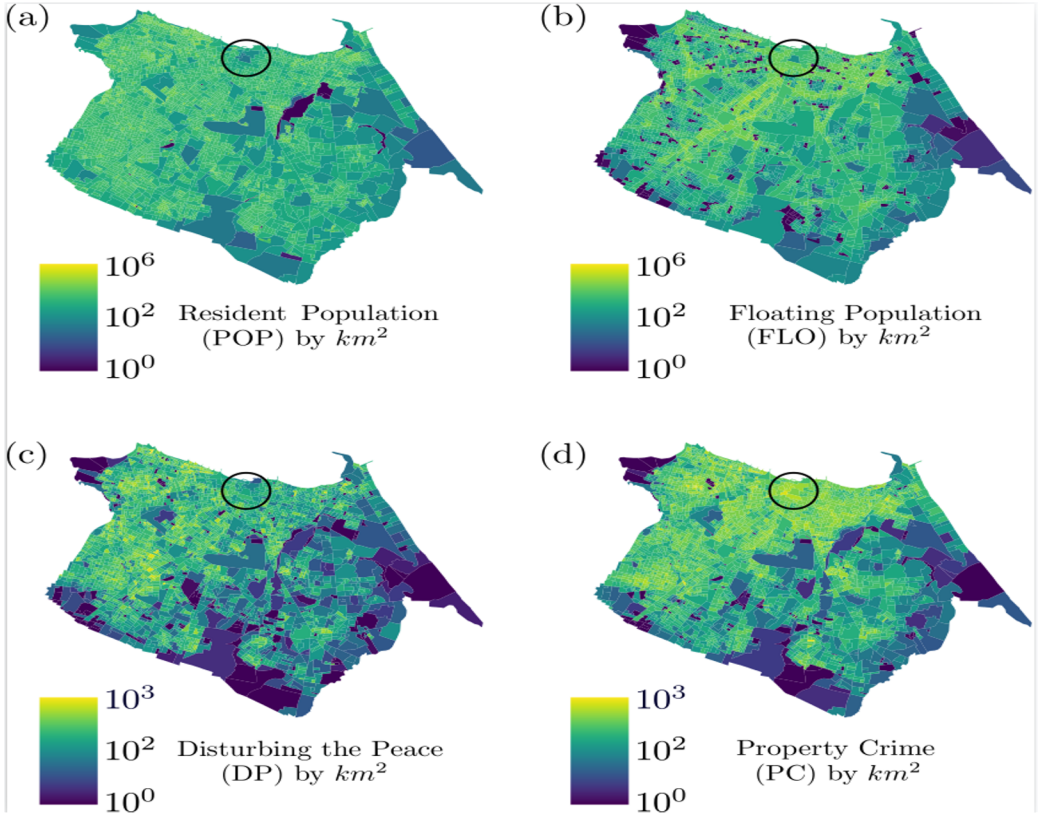
- The literature focus on the macro-scale (inter-cities)
  - Residential Population is the main proxy of the social influence in this context
  - Few practical effects for Law Enforcement
- Looking into the city (micro-scale)
  - Are there allometric relations inside a city?
  - Residential population is the unique dimension that explains this?
  - What is the role of people's movement?

Datasets

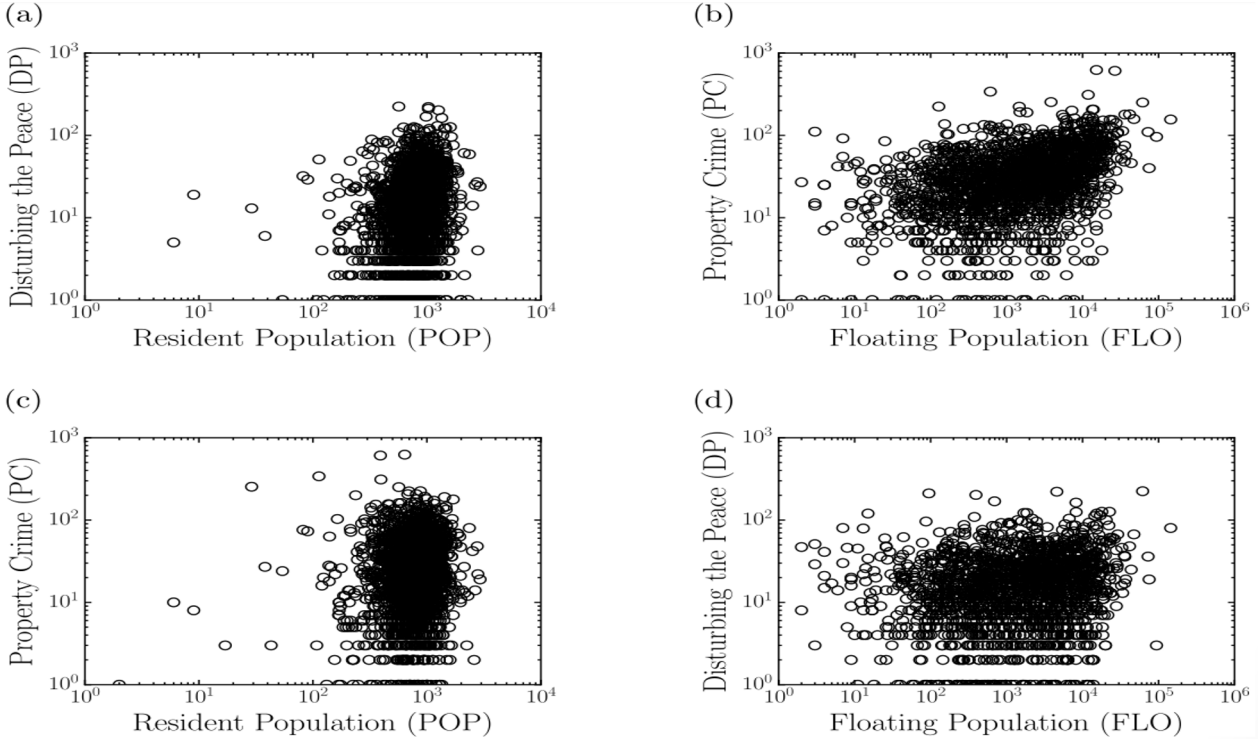
- City of Fortaleza
  - 3043 census tracts
  - 313 km²
- Resident Population (POP): ~2,4 M (2010)
- Floating Population (FLO): ~700 K/day (2015)
  - OD matrix generated from bus users *
- Property Crime (PC): ~81 K (2015)
- Disturbing the Peace (DP): ~53 K (2015)

- * Caminha et al. IEEE Smart City Conference, 2016
- Caminha et al. PLoS ONE 12(2): e0171609,2017

Crime Density



Allometry from Census tract



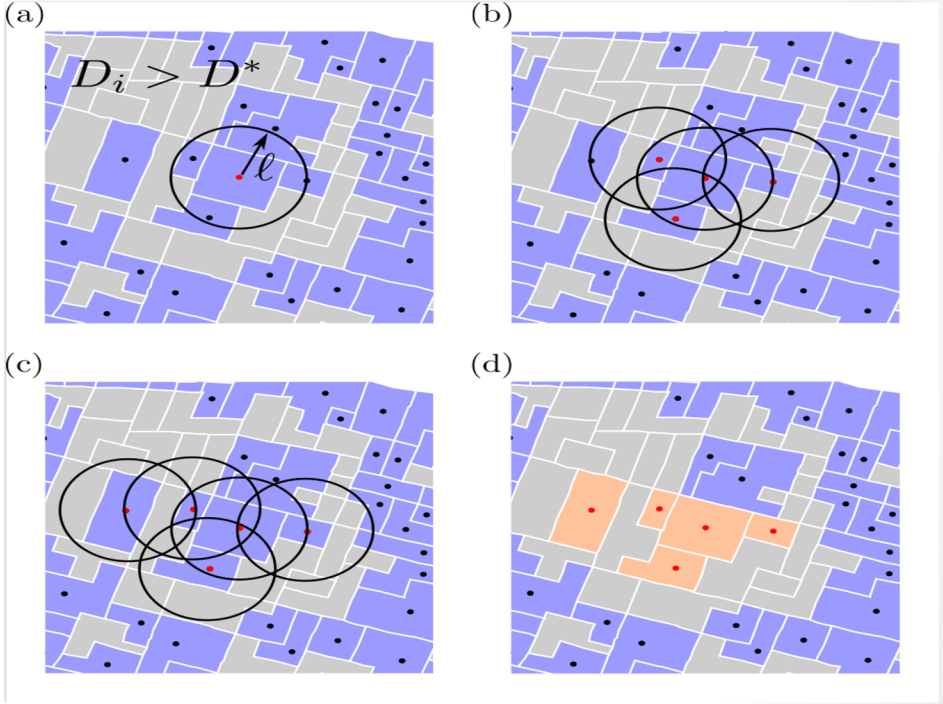
Estimating the boundaries of Social Influence

City Clustering Algorithm (CCA) (Rozenfeld et al. 2008)

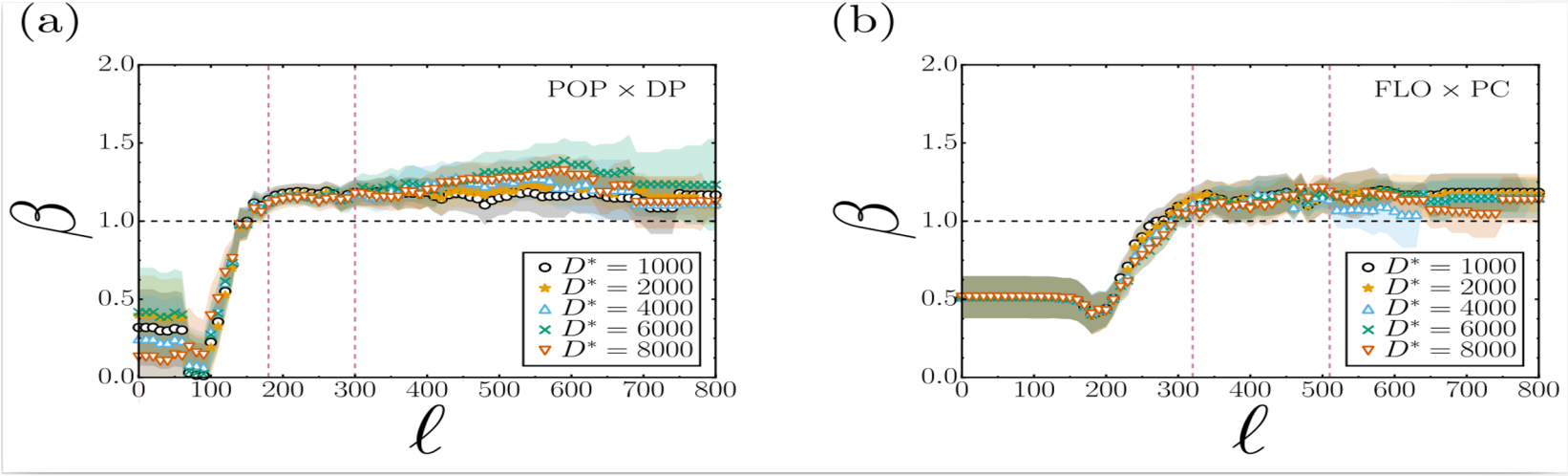
Two parameters:

Threshold of populational Density (*D**)

Threshold of distance (ℓ)

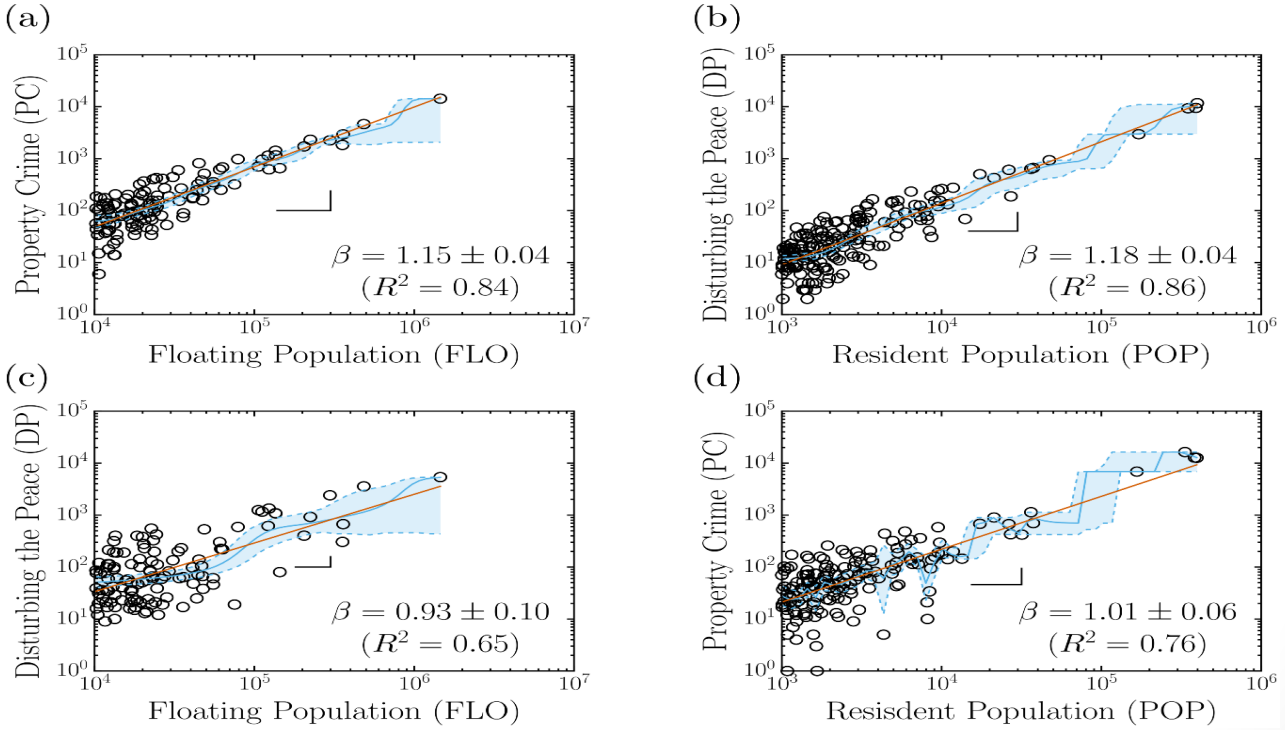


Values of β in different divisions of the city



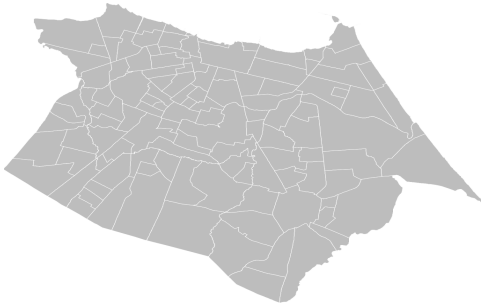
In more than 80% of the city divisions
superlinear relation between POP X DP e FLO e PC was found

Superlinear relation between population and crime



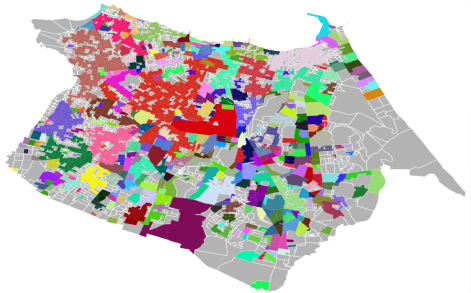
Impact in Police Allocation

- Resident Population Allocation (RPA) Strategy – police allocation per neighborhood
- Floating Population Allocation (FPA) Strategy – police allocation per clusters of floating population
- Clusters and Neighborhoods are composed by census tract
- Allocation is heterogeneous (proportional to the number of crimes in a census tract)



RPA

X

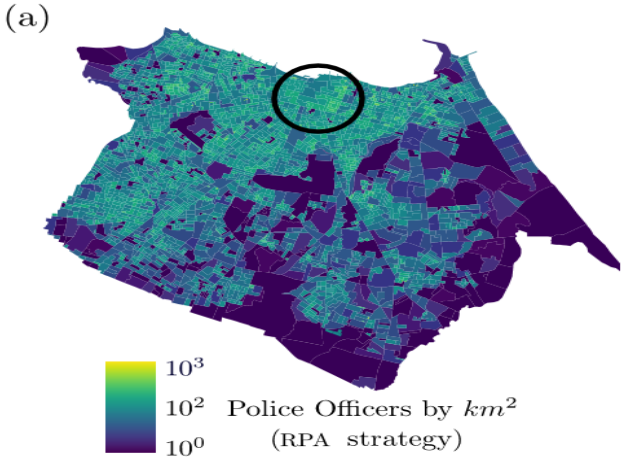


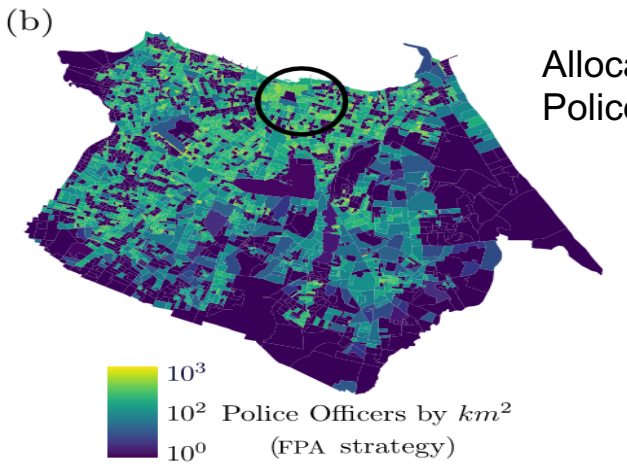
FPA

Caminha and Furtado, IEEE Intelligence and Security Informatics, 2017

Simulating the Allocation of Resources

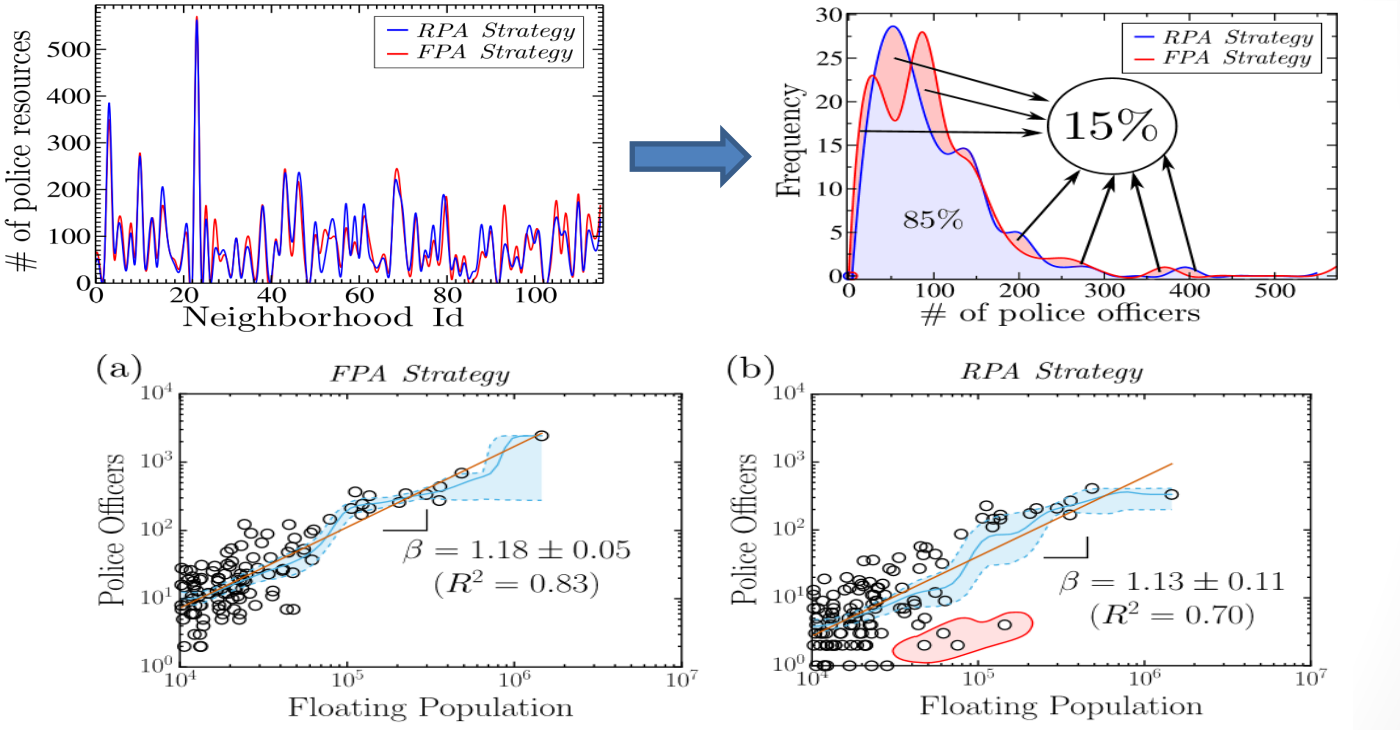
- The FPA Strategy allocates more resources in areas with more flow of people



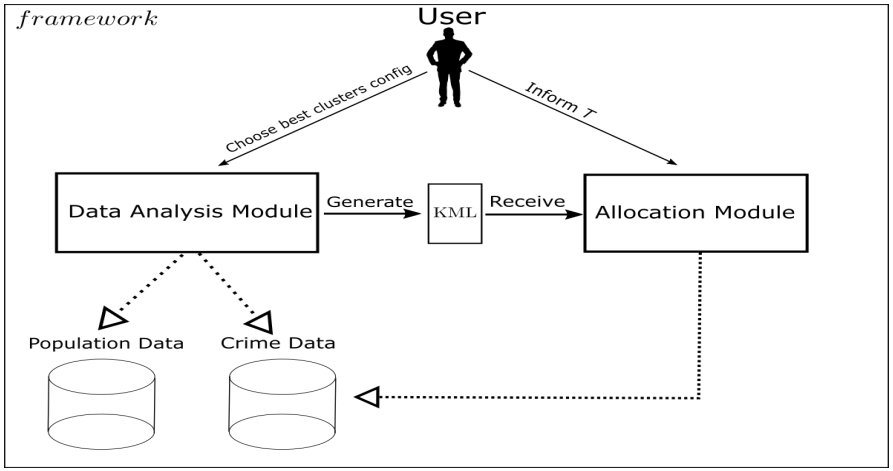


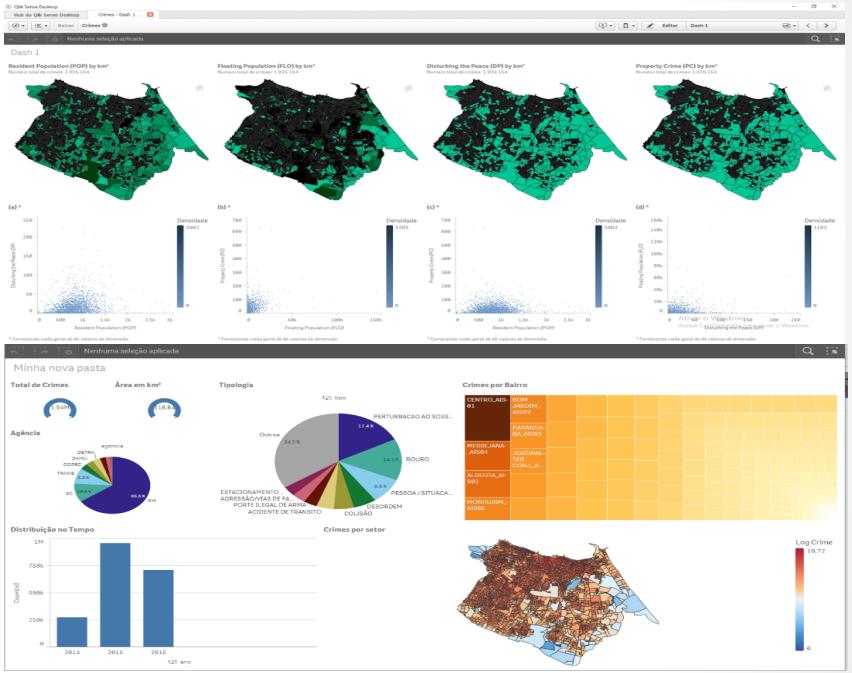
Allocation of 10.000 Police officers

Difference between strategies



Software to Support Analysis and Allocation





Conclusion

- The super linear relation between floating population and property crime suggests that the increase of people's flow in a region leads to a disproportional increase in crimes against property in that region
- These results have impact the way police allocation has been done as well as open the way for quantifying the sociological theories (e.g. is there a super linear relationship based on the motivation offender?)

Crime and Human Mobility

PLOS ONE | PUBLISH ABOUT

OPEN ACCESS PEER-REVIEWED

RESEARCH ARTICLE

Human mobility in large cities as a proxy for crime

Carlos Caminha, Vasco Furtado, Tarcisio H. C. Pequeno, Caio Ponte, Hygor P. M. Melo, Erneson A. Oliveira, José S. Andrade Jr.

Published: February 3, 2017 • https://doi.org/10.1371/journal.pone.0171609

EPIA Conference on Artificial Intelligence

EPIA 2017: Progress in Artificial Intelligence pp 41-50 | Cite as

Towards Understanding the Impact of Crime on the Choice of Route by a Bus Passenger

Authors Authors and affiliations

Daniel Sullivan, Carlos Caminha, Hygor P. M. Melo, Vasco Furtado

Context

Big data analysis of users who use a bus as a way of transportation

- Fortaleza 2,5 million inhabitants
- In average, 1 million people take a bus daily
- It was possible to estimate:
  - Origin-Destination (OD) of 60% of the passengers
  - The complete Real Route of 30% of them

Some of the findings:

- Most of the users do not take the optimal route (in terms of distance or time travel)
- Users typically commute at terminals rather than bus stops

Agent-Based Simulation

The impact of crime in Human Mobility?

- The impact in route choice

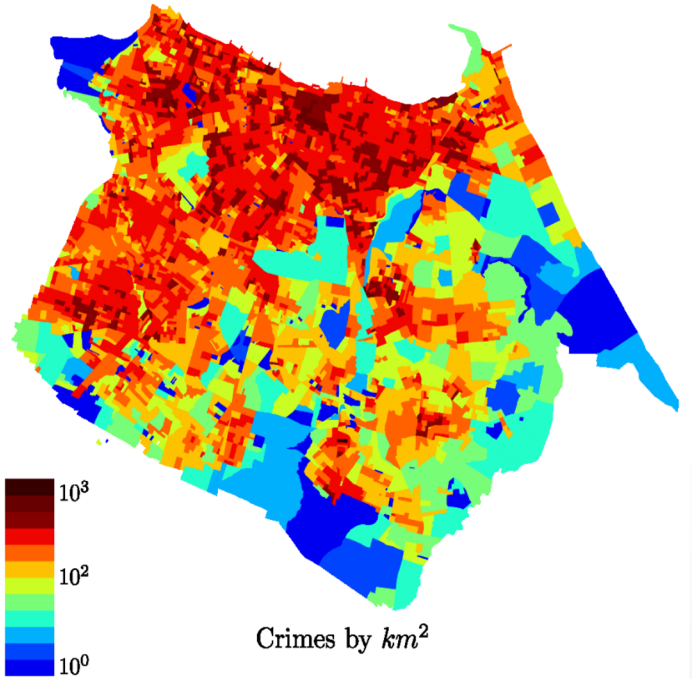
Goal: to support the creation of different scenarios based on the passenger choice

- Understanding the impact in the Public Transport System – PTS

Datasets

98431 property crimes in Fortaleza (09/2014 to 06/2016)
Mobility:

GPS and Ticketing
4784 bus stops
1800 buses
623 routes
31000 trips



MAB Simulation

Passenger

- Choose a route
- Embark in the Origin and disembark in the Destination
- Passengers embark only if there is a empty place, otherwise they wait for other bus

Bus

- Move from a stop to another following a pre-defined route
- A particular line makes several trips per day
- Termination: there is no bus with a route to follow (time expires)

AB Simulation

One-day simulation

One minute tick

Passenger distribution follows Poisson from OD

Bus speed is Gaussian based on GPS data

Each bus stop region has a rate of crime (crime per population)

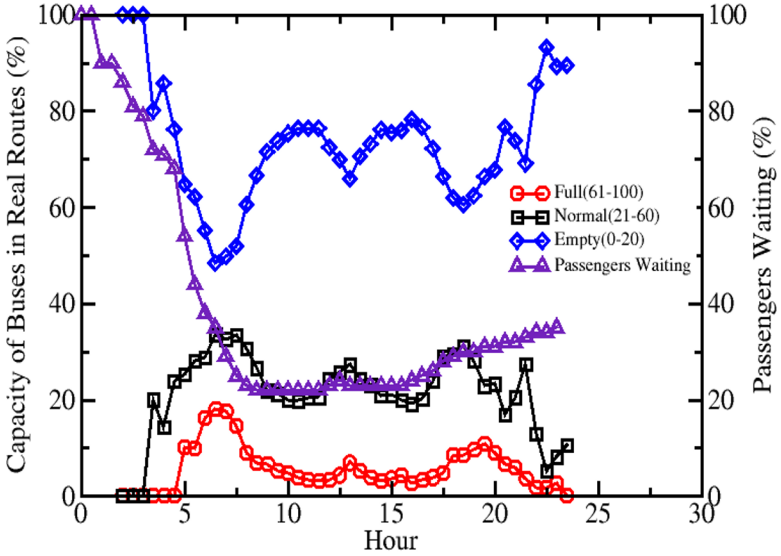
Results:

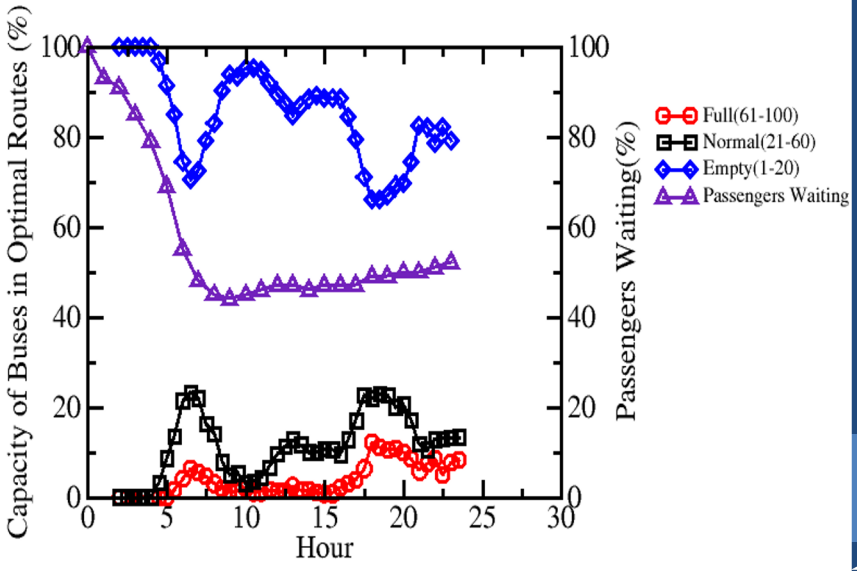
- Bus overcrowding
- Average waiting time

Results

Varying the choice of the user

- real route vs the optimal (in time) route





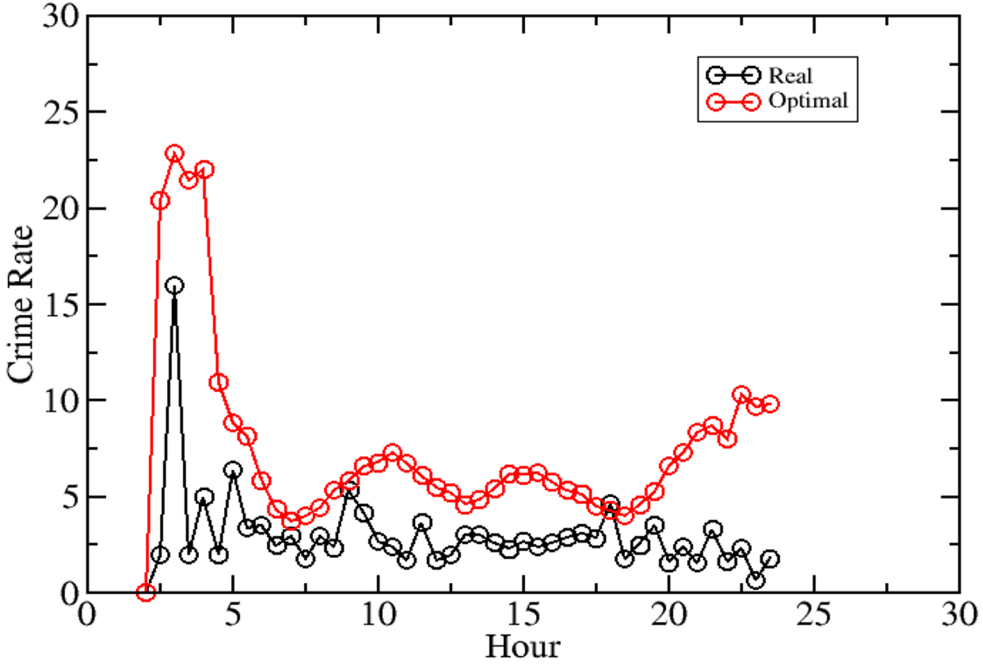
Results

- ✓ PTS is more efficient when passengers follow the “real” strategy
  - When passengers choose the optimal route:
    - Less overcrowding
    - Increase waiting time

- ✓ It seems that the PTS has been gradually driven to lead the user go to the terminals !!

Results

Average crime rate(crime per floating population) of Bus Stops chosen by the users to commute depending on the strategy (real vs optimal)



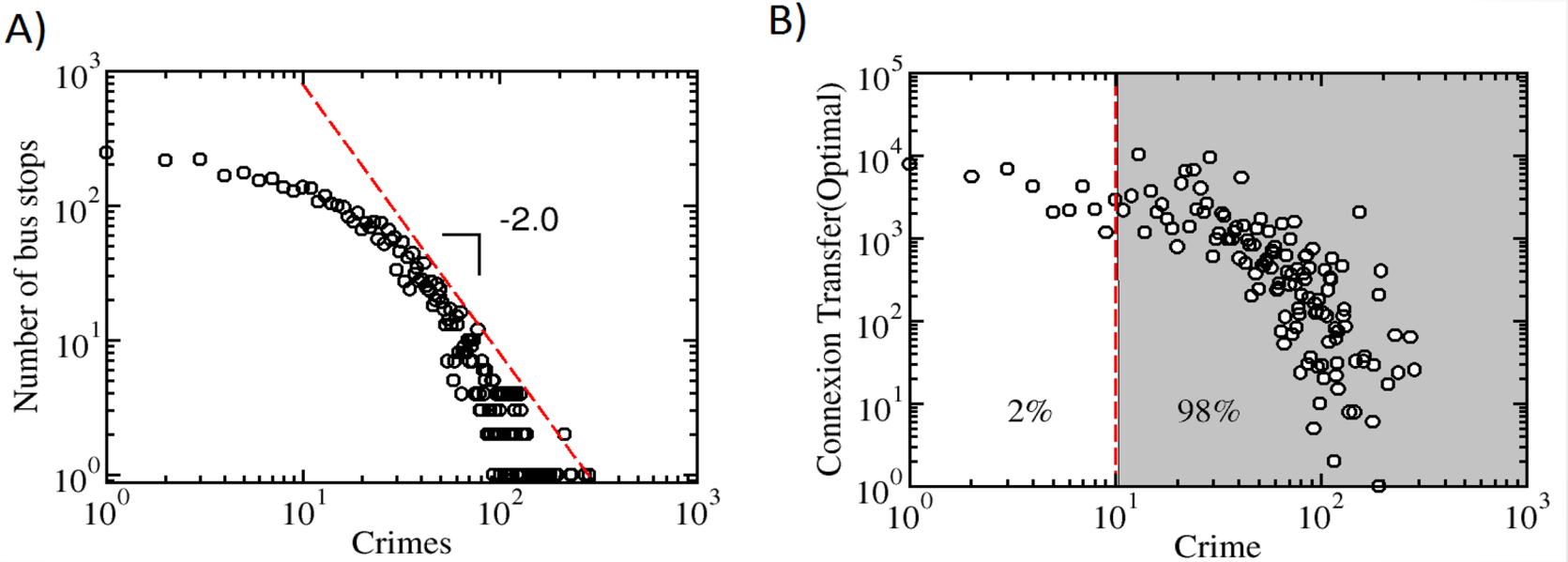
Do passengers know that a bus stop region is dangerous?

Is this influencing their decision on route choice ?

Data Analysis

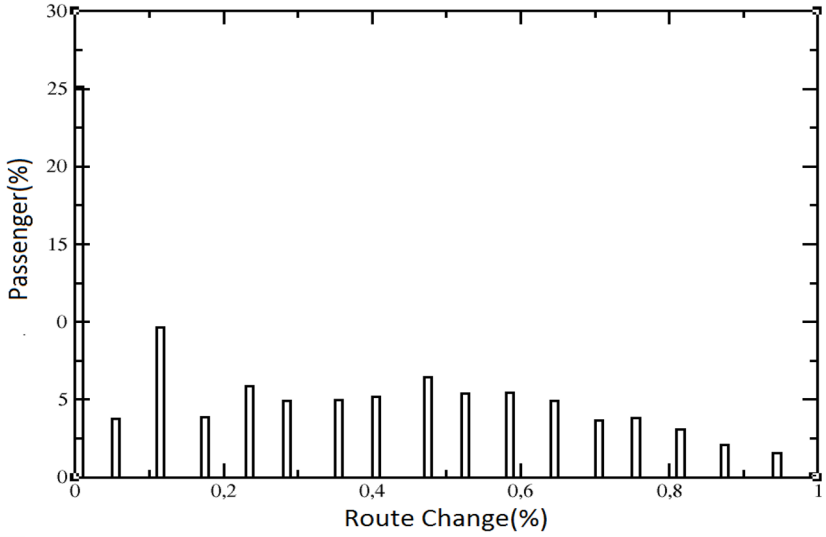
A power law for crime per bus stops

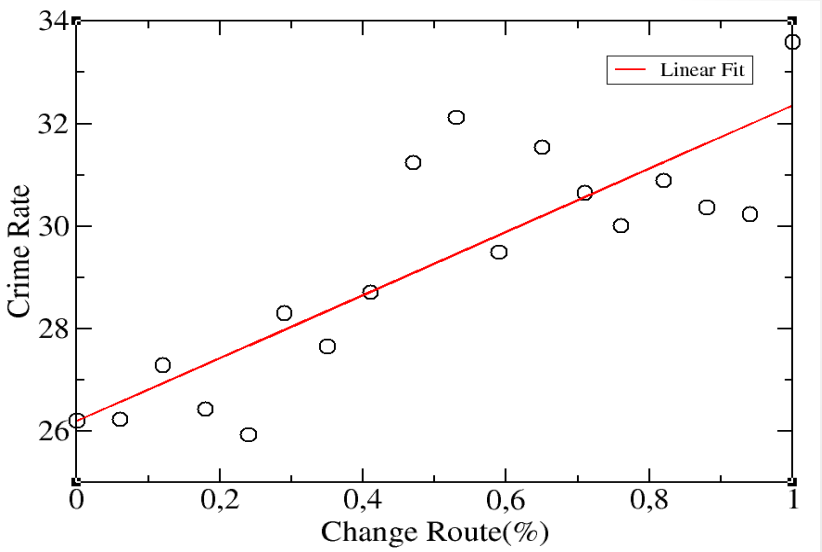
The best bus stops for commuting have more than 10 crimes



Data Analysis – On Going Work

Do the users change weekly their routes during a certain time?





Four Months (18 weeks)

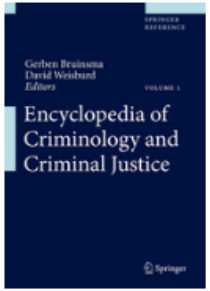
R2=0,84

Conclusion

Multiagent Crime Simulation is a novel field with many possibilities of development of tools for helping Law Authorities

A Data Mining approach will help to characterize the users in order to establish the best parameters for a multiagent simulation

Further Reading



Encyclopedia of Criminology and Criminal Justice

Editors: **Bruinsma**, Gerben, **Weisburd**, David (Eds.)

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Simulation as a Tool for Police Planning

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