

Business Applications of Game Theory and Machine Learning

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blindspot solutions



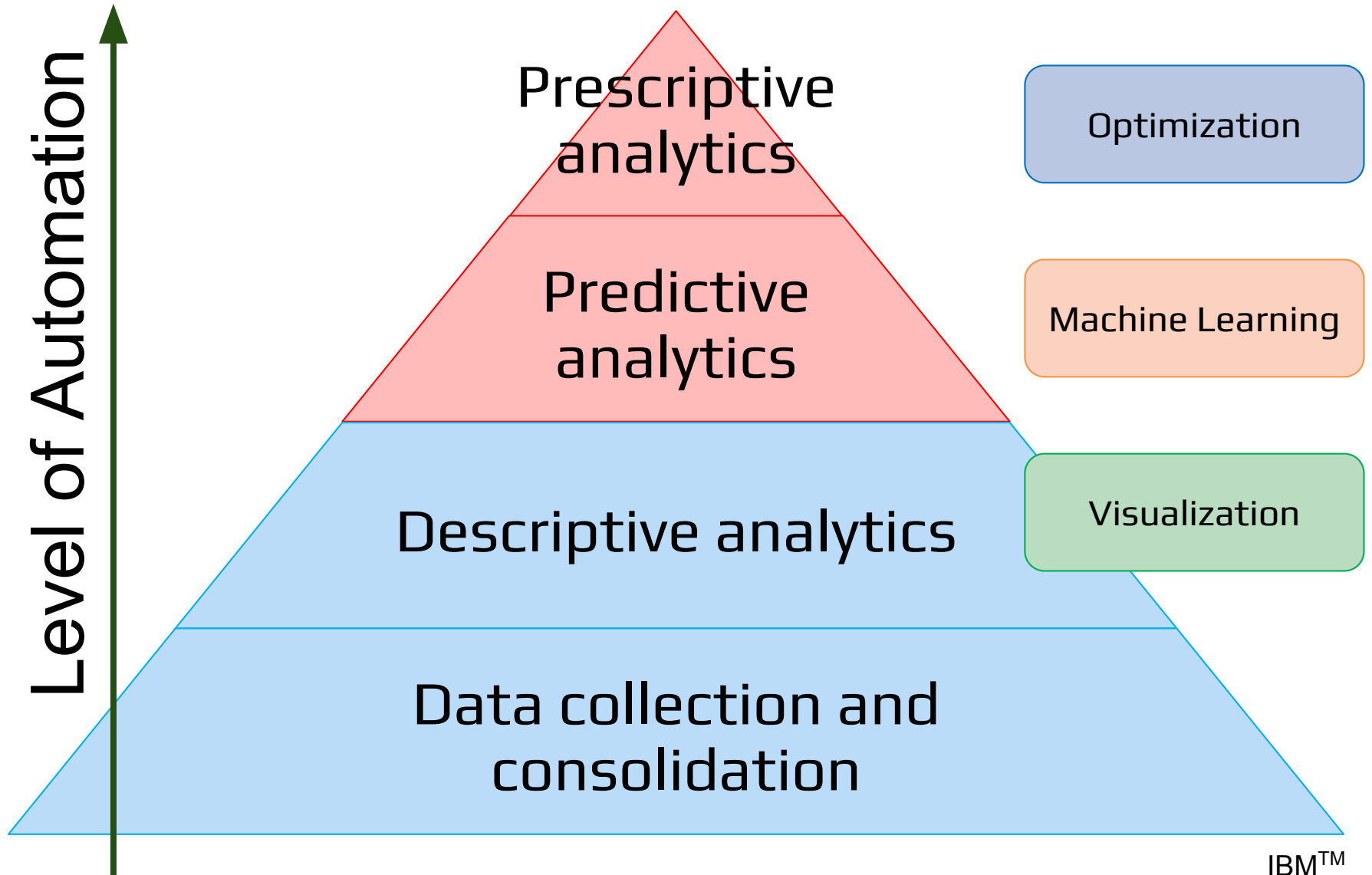
DATA ANALYSIS: Big data processing and analysis using machine learning



PLANNING & SCHEDULING: Logistics planning, production planning, workforce management, SCM



STRATEGIC OPTIMIZATION: Optimal audit processes, randomized asset allocation



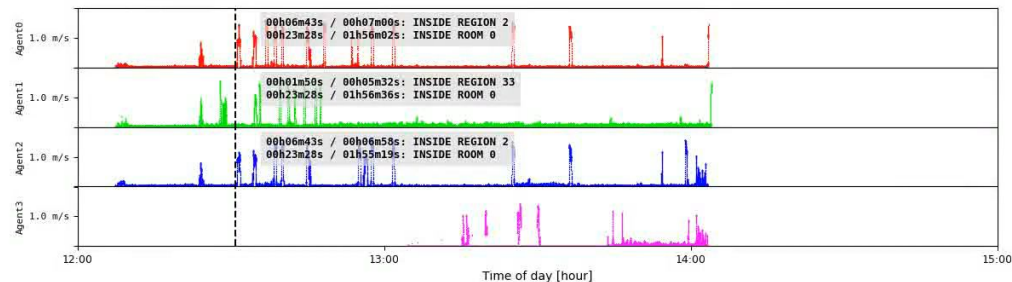
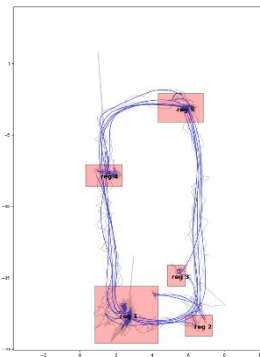
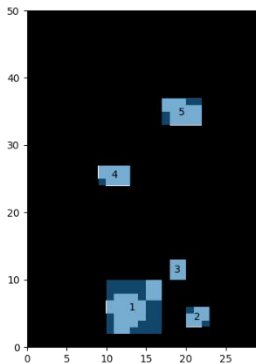
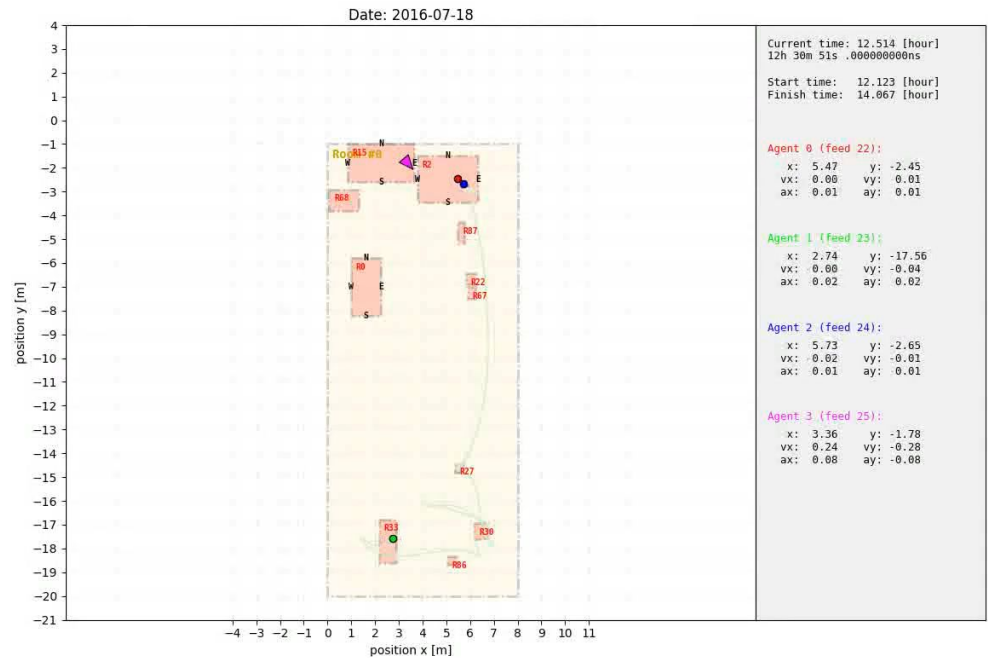
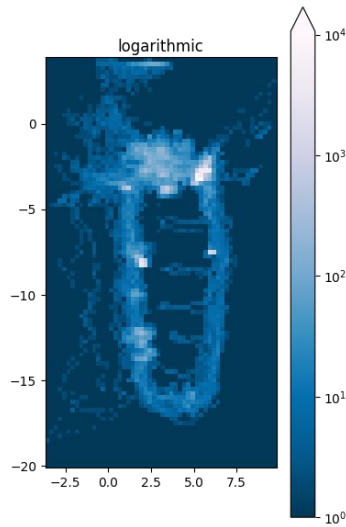
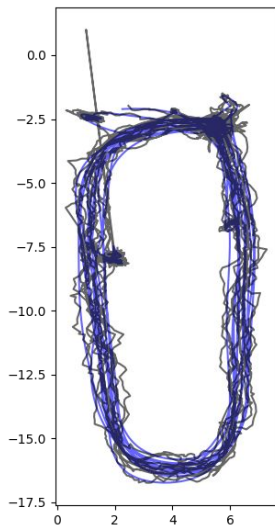
Let's have a look

at some examples...

Analysis of Motion Data

Extraction of regions, smoothing of trajectories

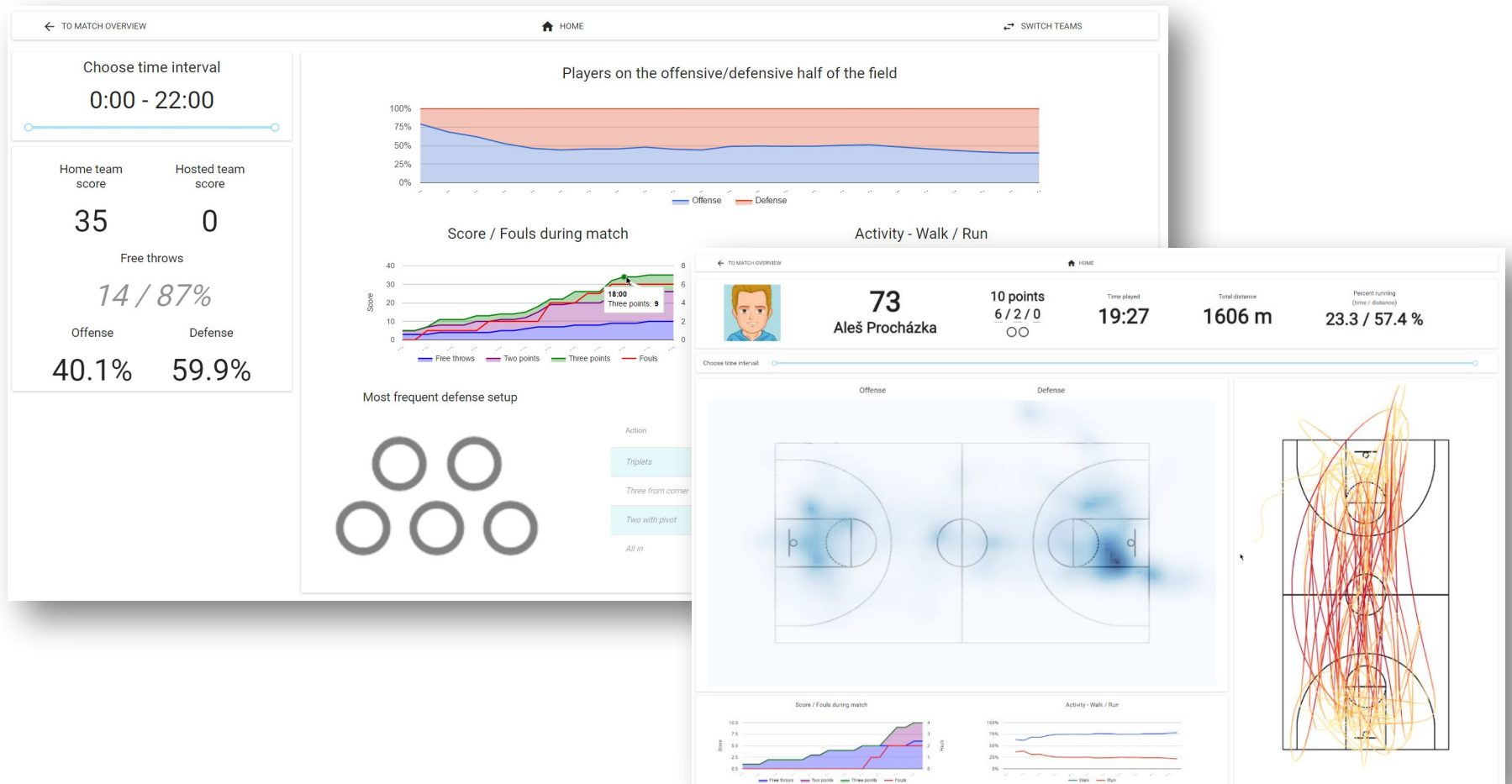
Raw data from motion sensors → smoothing of trajectories → extraction of regions
Estimation of directions, speeds, entry/exit of regions



Analysis of sport data

Inter and intra match/training player/team statistics

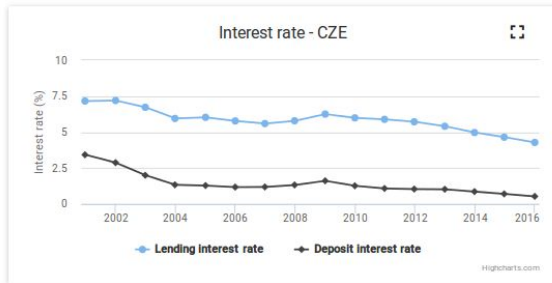
Raw data from motion sensors → smoothing of trajectories → extraction of player movement → extraction of joint actions → merge with match records



Analysis of Market Signals

Intelligent Portfolio management tool for investors and traders

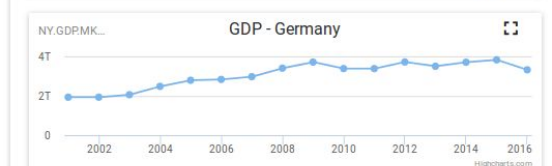
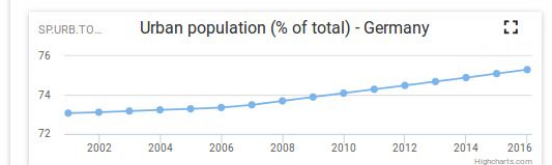
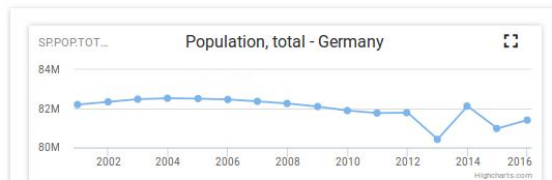
Collection of large set of fundamental and market data | Analysis of price dependency for selected stocks
 Long and short term price trend explanation | Automatic alert generation



Company name	Volkswagen AG
Employees	613,625
Net profit margin in Q2 (Jun '16)	2.13%
Address	Berliner Ring 2, WOLFSBURG, Germany

$$f(x) = [0.813 \cdot \text{POAHY}] - [0.423 \cdot \text{GDPGER}] + [0.413 \cdot \text{DDAIF}] + [0.413 \cdot \text{BAMXF}] + [0.1 \cdot \text{TPOGER}] + [0 \cdot \text{UPOGER}]$$

Correlation: 0.6



[VW broke consumer laws in 20 countries](#)
 Seeking Alpha - Sep 5, 2016
 The European Commission has found that Volkswagen (OTCPK:VLKAY) broke consumer laws in 20 EU countries by cheating on emissions tests, according to Germany's Die Welt.

[Daimler AG Dives in the Same Pool as Tesla Motors Inc & Volkswagen AG \(ADR\)](#)
 TCC - Sep 3, 2016
 The Germany-based luxurious car maker Daimler AG (OTCMKTS:DDAIF) announced its plans to introduce at least six models of electric vehicles, as the maker of Mercedes-Benz aims to give a thrust of competition to its rival compatriot, Volkswagen AG (ADR) ...

[Volkswagen AG \(ADR\) Under Fire In Australia](#)
 Bidness ETC - Sep 1, 2016
 Volkswagen AG (ADR) (OTCMKTS:VLKAY) is going through a hard time due to the emission scandal that continues to haunt the company.

[Is Volkswagen AG \(ADR\) Chasing Tesla's Dream With Long-Range EVs?](#)
 Bidness ETC - Aug 30, 2016
 Volkswagen AG (ADR) (OTCMKTS:VLKAY) is trying to put behind its diesel emission fraud, that has tainted the company's image for nearly a year.
[Tesla Motors Inc to Lose Competitive Edge in Future](#) - Smart Stock News

Predicting your next shopping basket



.... And what about real-time logistics?

And warehouse inventory?

And warehouse location?

Threat detection

Tons of data (Spark, yay!)
Tons of threats

Zero-day vs. repeated attacks

Sophisticated attacks

Prevention of attacks

IoT-based attacks
Cyber-threats in autonomous *

VS.

Incident response

I've been pwned - what now?

Complex "playbooks"

Fast reaction times

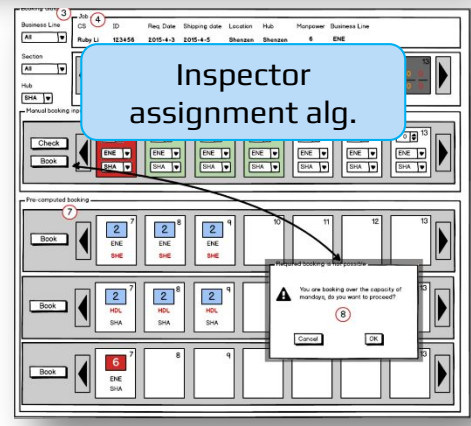
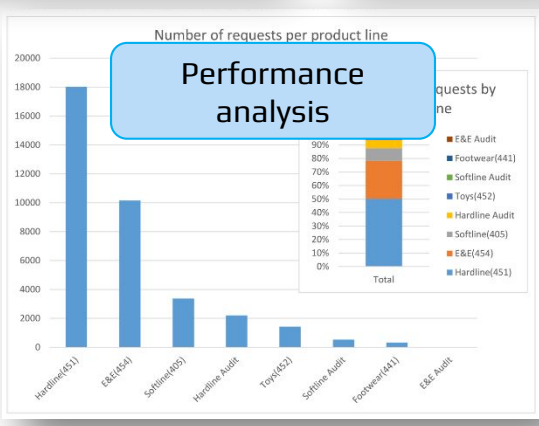
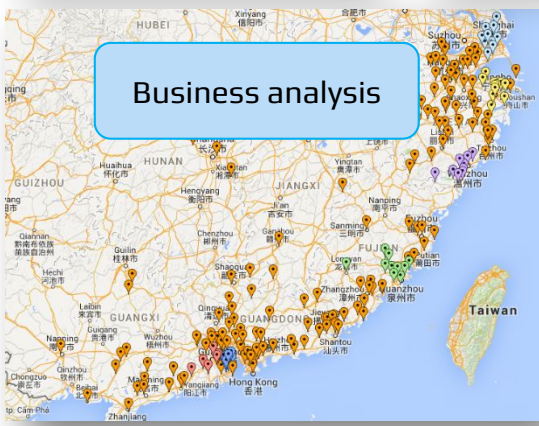
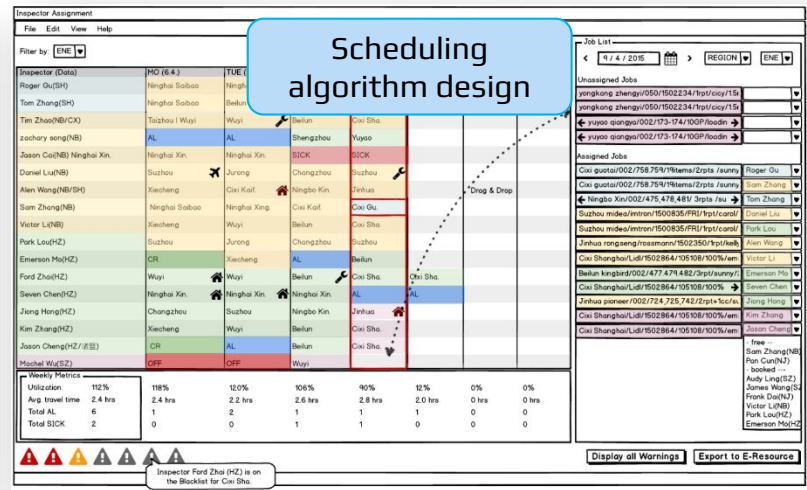
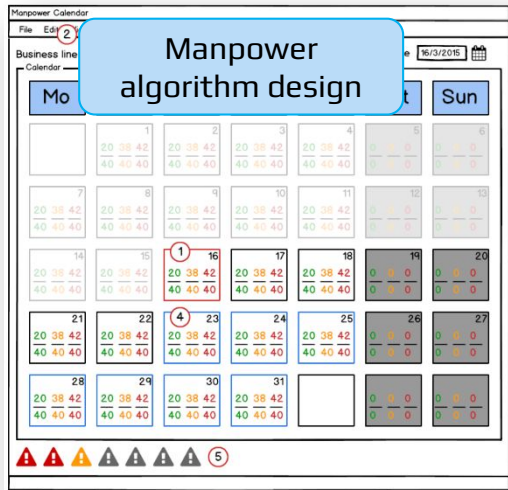
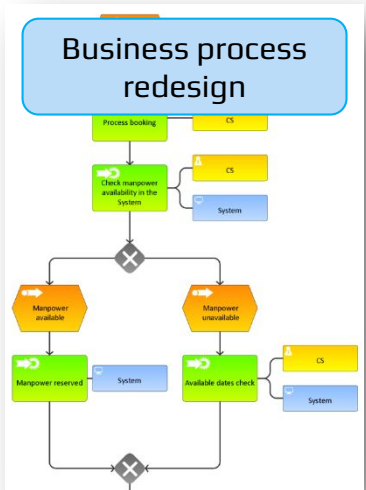
vs.

Audit trails, Lawyers, Processes

Unpredictable inspectors

Optimization of pre-shipment inspection processes

Analysis of pre-shipment inspection operations | SW specification | Comparison with other inspection business lines | Optimization algorithm design and implementation

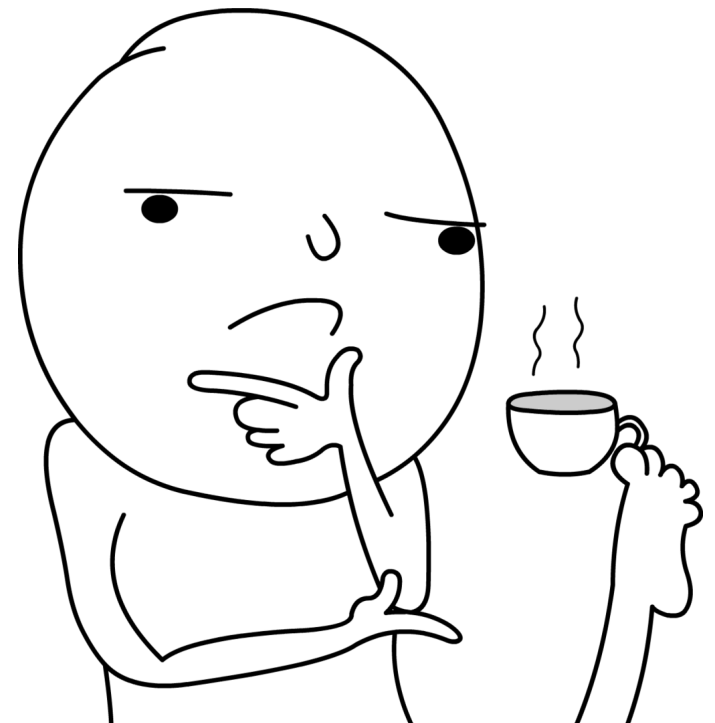


Predictive Policing

Case study of mixing stuff together

But first ... What is game theory?

...Yet another optimization problem



Quick intro - airport security game



Who are the
players?

What are the
strategies?

What are the
utilities?

How to solve a game?

Nash Equilibrium (NE)

Strong Stackelberg Equilibrium (SSE)

Bayesian SSE

Correlated NE

Subgame perfect NE

...

Well, mathematically...

Nash Equilibrium (NE)

		p1	p2	p3
		A1	A2	A3
q3	B1	12,2	-1,6	10,8
q2	B2	0,0	0,5	12,3
q1	B3	32,-5	-2,3	0,9

min \mathcal{V}

$$\mathcal{V} \geq \sum_{i=1}^m p_i \cdot \mathbf{A}_{i1}$$

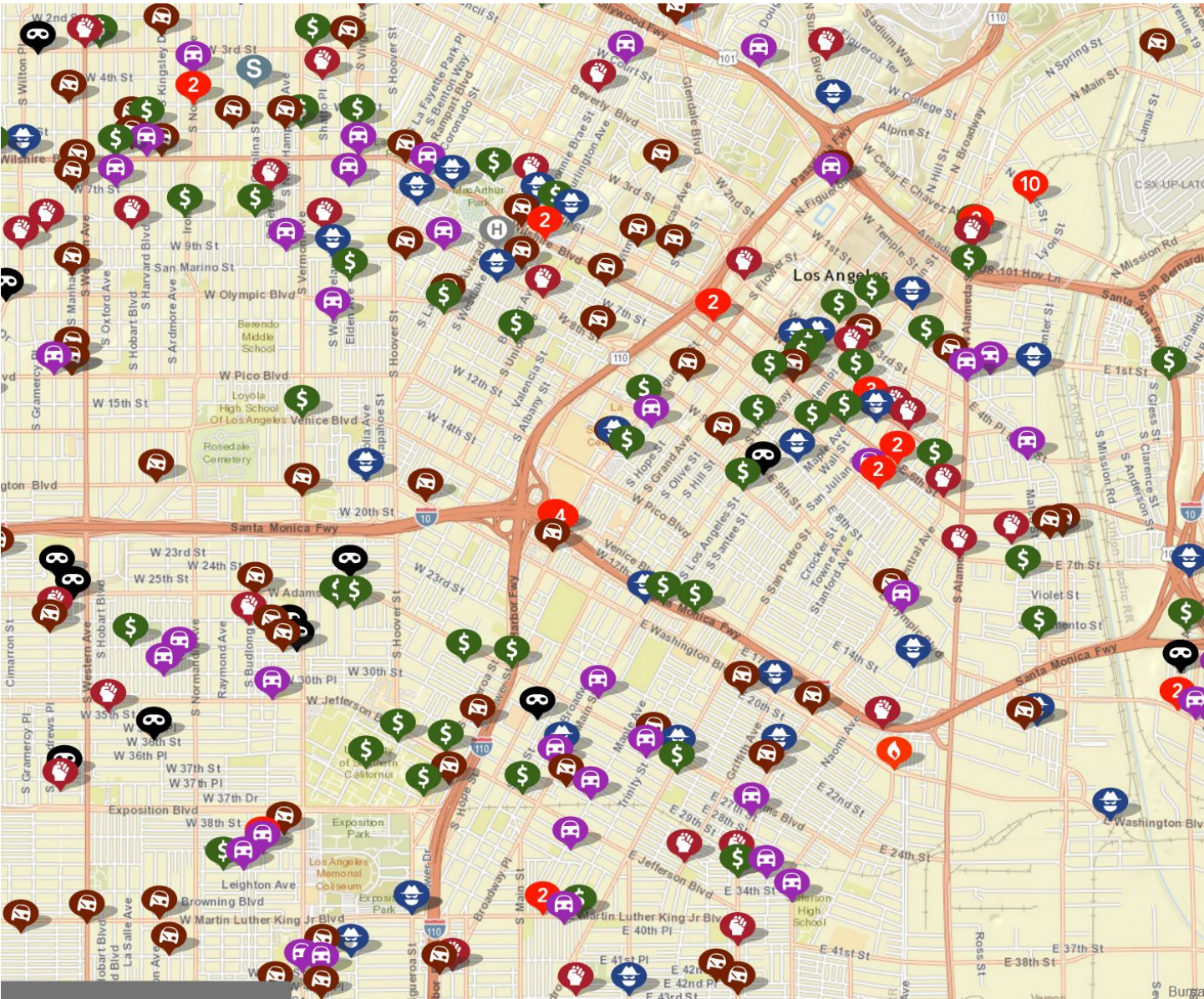
⋮

$$\mathcal{V} \geq \sum_{i=1}^m p_i \cdot \mathbf{A}_{in}$$

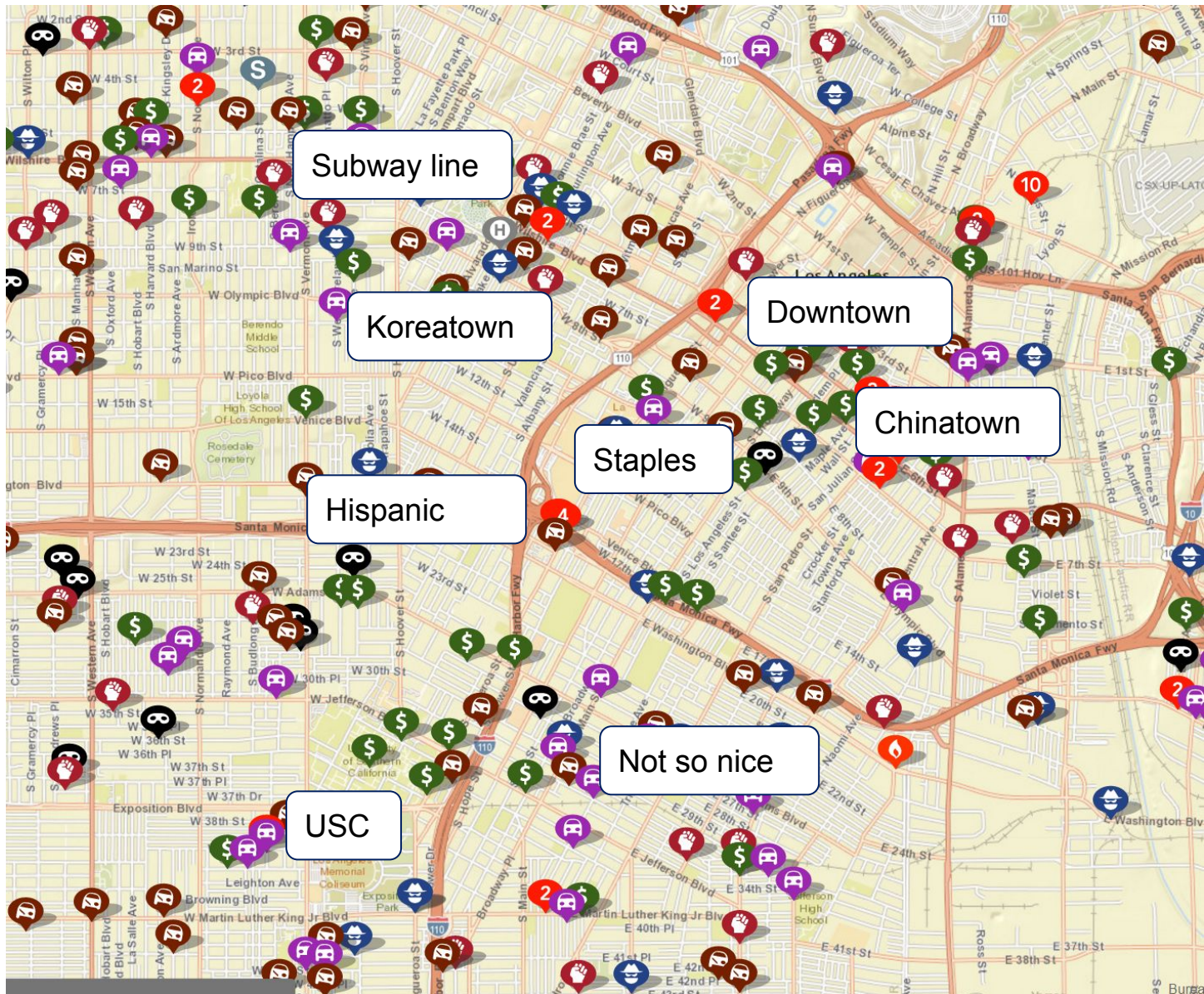
$$\sum_{i=1}^m p_i = 1$$

$$p_i \geq 0$$

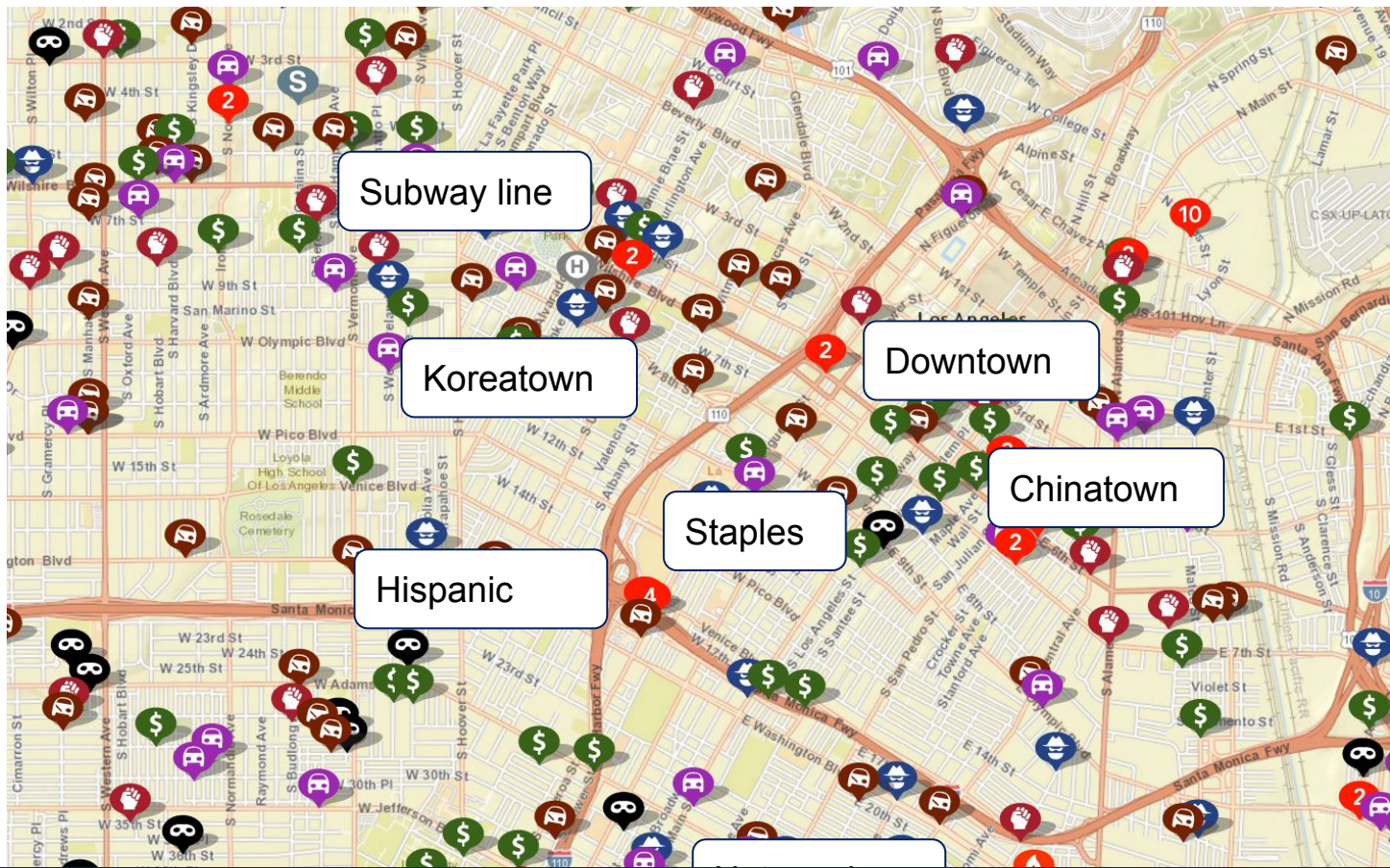
Motivation - LA Crime



Motivation - LA Crime



Motivation - LA Crime



How to patrol this s...?



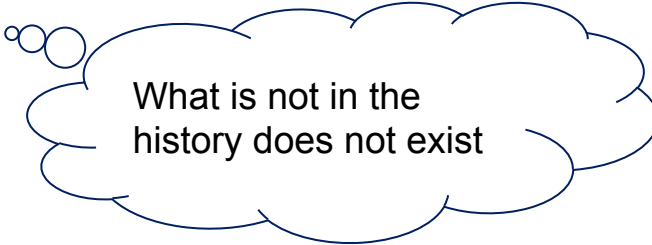
The solution

1. **Data collection** - all crime relevant data
 - a. Demographics
 - b. Weather → haha, it's LA → heat waves!
 - c. Events (sports, school, culture)
 - d. Housing vs. commercial
 - e. Transportation network
 - f. Temporal data
 - g. **Crime reports**
2. **Model of criminal behavior** - how criminals think
 - a. Petty theft vs. GTA vs. Gang wars
 - b. **Data-based (ML) vs. Game-theoretic model (next slide)**
3. **Scheduler** of policemen
4. (Reporting / Analysis)

Sceptical view on ML and GT

ML approach

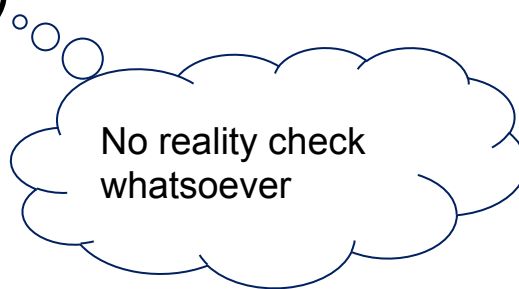
1. Historical data
2. Model through generalization over historical data
3. Predictions from model (?)



What is not in the
history does not exist

Game theoretic approach

1. Goals, strategies, costs + rewards, rationality model (?)
2. Equilibrium computation (?)
3. Principally no historical data needed (?)



No reality check
whatsoever

Game-theoretic model - scheduler

Bayesian Stacklerberg Game

including rationality models - Quantal response, prospect theory, ...

Game - bad guys react on the good guys' movement

Stacklerberg - Good guys have to commit to a patrolling strategy, they are observable, they "move" first

Bayesian - multiple types of players (robbery vs. bike theft)

Solution (Tambe et al.) - Equilibrium of the game

Randomized schedule

sequence of micro-regions to visit

Game representation

Car theft - probability 0.6

	A1	A2
B1	12,2	-1,6
B2	0,0	0,5
B3	32,-5	-2,3

Robbery - probability 0.4

	A1	A2	A3
C1	1,-2	-2,16	23,0
C2	10,2	7,-4	2,13
C3	3,-5	-2,0	1,2

Game representation

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Get the numbers! ML-based approach

Modus operandi based on crime reports

burglaries happen at night with 2 robbers in these districts

Clustering of crime types

there are two types of burglaries - opportunistic vs. planned

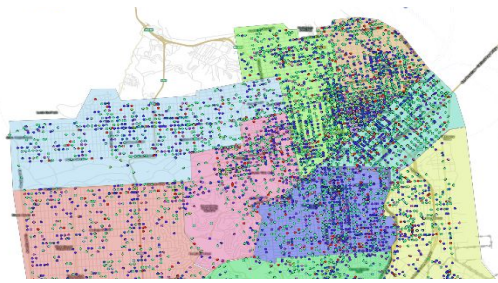
Temporal forecasting of crime and influencing factors

there are weekly/monthly/yearly trends in crime (rate)

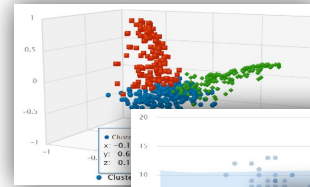
Spatial forecasting of crime

there are long term shifts in crime

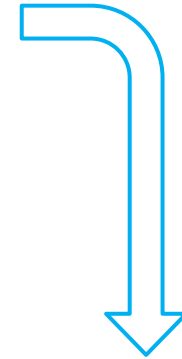
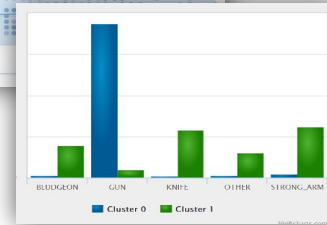
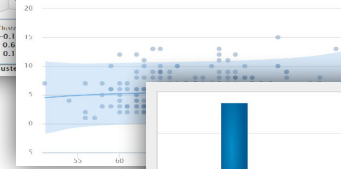
The solution



Analysis of crime and environmental datasets



A set of Rules



Environment Model + Forecast

$$\theta \sum_{i \in \{1,2\} \times E} |w_{ij} + z_{ij}| + \alpha \cdot \sum_{i \in V} |w_i| + \beta \cdot |R_{max}| + \gamma \cdot \sum_{i \in \{1,2\} \times E} u_{ij} \quad (6)$$

$$\sum_{i \in \{1,2\} \times E} f_{ij}^m + R_{max} = \sum_{i \in \{1,2\} \times E} f_{ij}^m \quad (7)$$

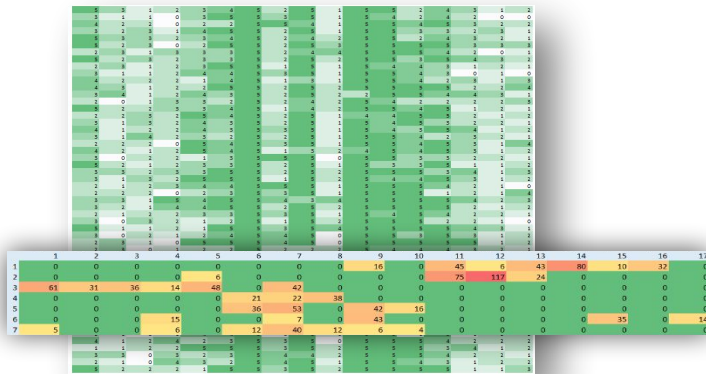
$$\sum_{i \in \{1,2\} \times E} f_{ij}^m + w_{ij} = \sum_{i \in \{1,2\} \times E} f_{ij}^m \quad \forall i, j \in V \quad (8)$$

$$f_{ij}^m + w_{ij} = \sum_{i \in \{1,2\} \times E} x_{ij}^m \quad \forall (i, j) \in E_{max}, \forall i_{max}, \forall j_{max} \in V \quad (9)$$

$$f_{ij}^m + z_{ij} = \sum_{i \in \{1,2\} \times E} x_{ij}^m \quad \forall (i, j) \in E_{min}, \forall i_{min}, \forall j_{min} \in V \quad (10)$$

$$f_{ij}^m = f_{ij}^m + u_{ij} \quad \forall (i, j) \in E \quad (11)$$

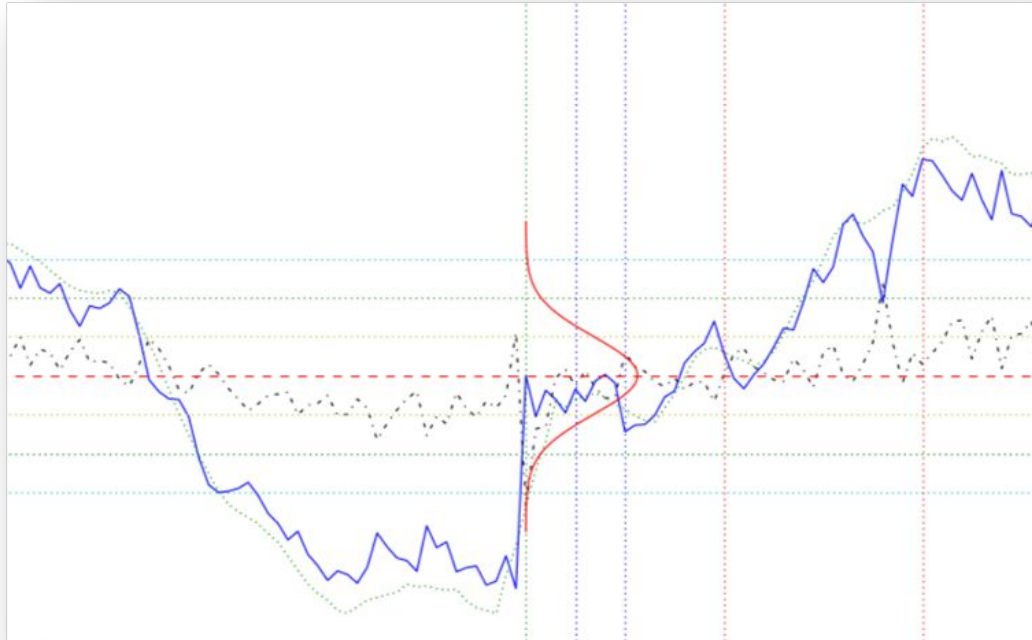
Mathematical model



Generated Dynamic Schedule for Police Forces

How well does we perform?

Detection of trend change after an event (i.e., after the introduction of the system)



Balloon effect - how to account for it?

Current Limitations of Game Theory

Majority of game-theoretical models in physical security are
(Bayesian) Stackelberg games
with zero-sum structure or security-game structure

Challenges of application

General-sum games (physical, cyber security, transport)

Multi-player games (trading)

Extensive form games (long-term interaction)

Imperfect information (transport, inspections)

Imperfect recall (existence of equilibria)

Rationality models - what is the best rationality model?

Possible areas of GT application

Cyber Security

Physical Security

Autonomous patrolling (Drones)

FinTech

Trading

B2B strategy - market modeling

Audits, Inspections, Regulations

GT applications - sporadic, but there is potential

Can I bring something from GT
to standard optimization problems?

Machine learning applications - vast!

Build a startup! Or is it too late?

Thank you.

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