



Discovering unknown unknowns in parking data by Formal Concept Analysis based Data Mining



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Process Improvement: What's up ?

- A process is a series of steps to achieve a GOAL.
- Each step should deliver added-value.
- The process should preferably achieve the goal in ONE pass.
 - ▶ **The 'First-time Pass Rate' is an important KPI !**
- Processes should be documented, enforced and audited. Ignoring this results in unknown process variations on the work floor...



Discovery versus Mining

Mining

= Searching for the 'main'/average results for a 'known' set of questions (unknowns)

Discovery

= Try to detect the 'exceptions', out of the box elements, typically unknown unknowns...






Long, Letitia A., Activity Based Intelligence: Understanding the Unknown, *Intelligence: Journal of U.S. Intelligence Systems*, Vol 20(2) Fall/Winter 2013, pp 7 – 15





What is a 'concept' ?

Taste: Sweet / Sour, Shape: Round / Long, Color: Red/Green/Yellow, Texture: Smooth/Bumpy







		Red	Green	Yellow	Round	Long	Sweet	Sour	Smooth	Bumpy
	Apple	X	X	X	X		X	X	X	
	Lemon			X	X			X		X
	Banana			X		X	X		X	
	Strawberries	X			X		X			X
	Grapes	X	X		X		X	X	X	
	Pear			X		X	X		X	

Based on : Wille R., „Formal Concept Analysis as Mathematical Theory of Concepts and Concept Hierarchies',
In Formal Concept Analysis, Eds B. Ganter et al., LNAI 3626, pp1-33, (2005)



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		Red	Green	Yellow	Round	Long	Sweet	Sour	Smooth	Bumpy
	Apple	X	X	X	X		X	X	X	
	Lemon			X	X			X		X
	Banana			X		X	X		X	
	Strawberries	X			X		X			X
	Grapes	X	X		X		X	X	X	
	Pear			X		X	X		X	

Every 'rectangle' of crosses is A 'concept'...!

A1 = ({Apple, Banana, Pear} , {Yellow, Sweet, Smooth})



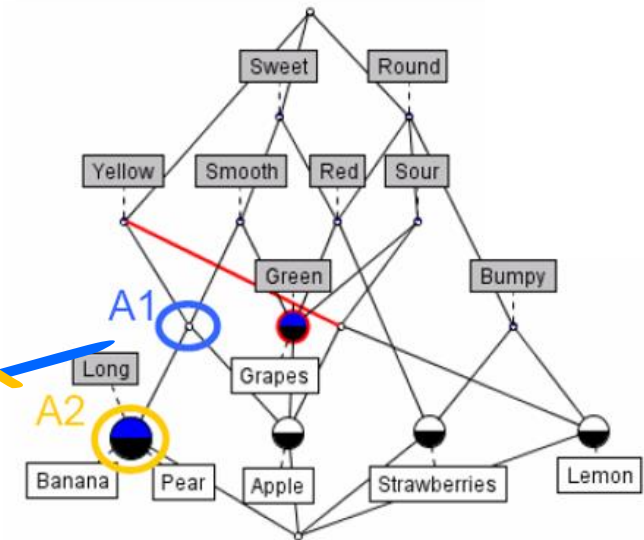
Concepts are ordered...

	Red	Green	Yellow	Round	Long	Sweet	Sour	Smooth	Bumpy
Apple	X	X	X	X		X	X	X	
Lemon			X	X			X		X
Banana			X		X	X		X	
Strawberries	X			X		X			X
Grapes	X	X		X		X	X	X	
Pear			X		X	X		X	

$A2 = (\{Banana, Pear\} , \{Yellow, Long, Sweet, Smooth\})$

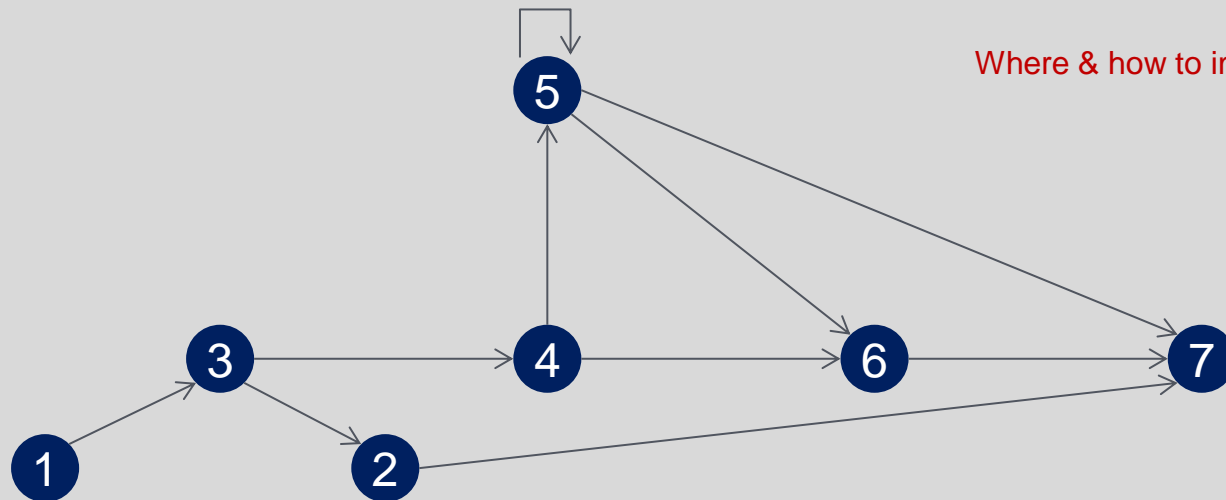
A2 is 'more special': less objects, but more attributes !

	Red	Green	Yellow	Round	Long	Sweet	Sour	Smooth	Bumpy
Apple	X	X	X	X		X	X	X	
Lemon			X	X			X		X
Banana			X		X	X		X	
Strawberries	X			X		X			X
Grapes	X	X		X		X	X	X	
Pear			X		X	X		X	





A Simplified Parking Rights Enforcement Process



- 1: Register the vehicle (incl. vehicle-ID) parked at a particular time & location
- 2: Search valid parking right for that vehicle-ID at the observed time & location
- 3: Valid parking right (and assume also it is correctly paid)
- 4: No valid (or nearly-valid) parking right found
- 5: Search additional information for payment (e.g. calculate the additional parking fine)
- 6: Issue payment request
- 7: End



Formal Concept Analysis Use case 1...

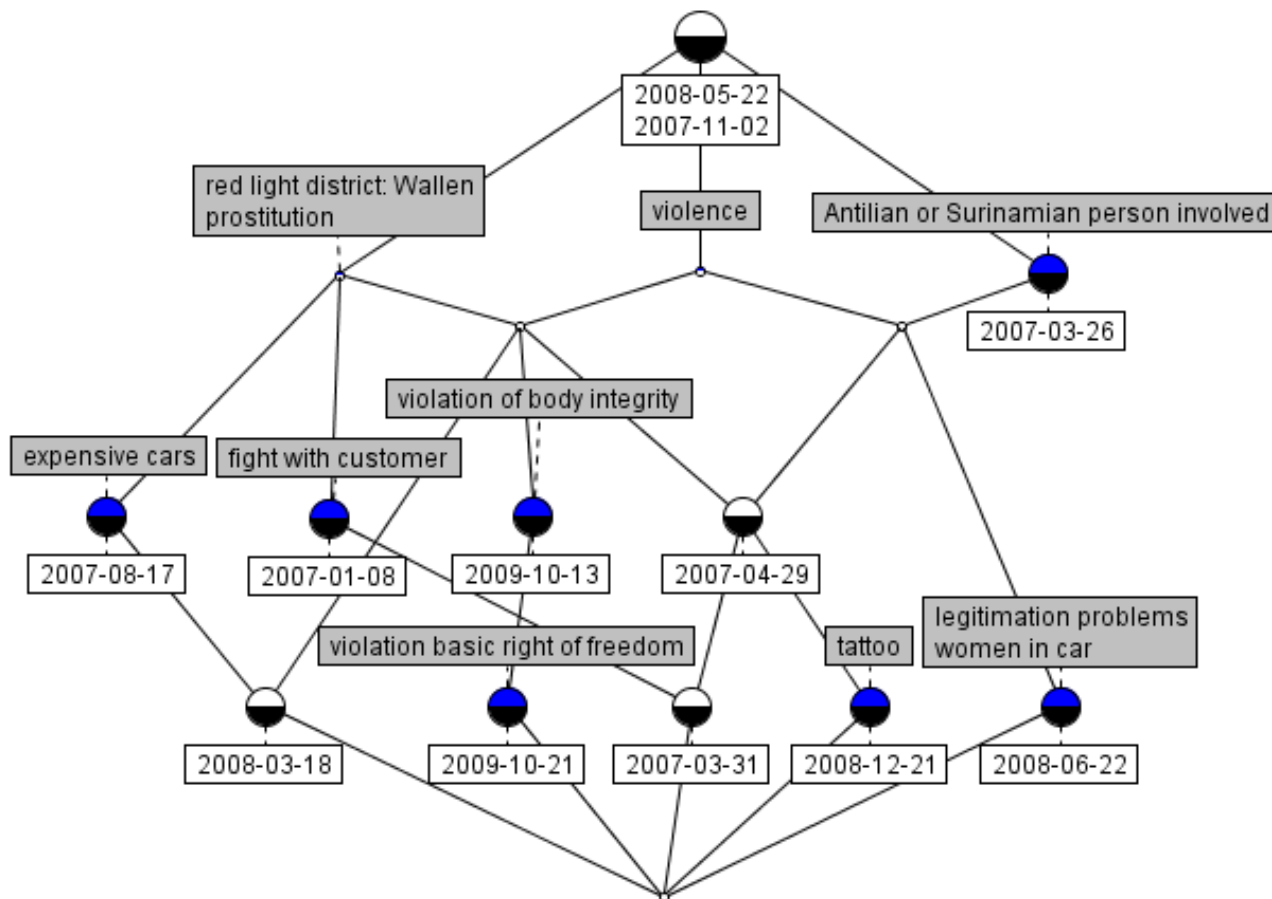
DISCOVER EARLY WARNING/REASONS for violations of parking rights...

- Consider 'INVALID PARKING RIGHTS' as one of the attributes in the concept lattice.
- Go in Discovery and detect the attributes that neighbor in the lattice to invalid rights.
- Eliminate stepwise the 'known' attributes and add (if needed) additional information attributes
- This technique has been very powerful in the context of POLICE Cases

Poelmans, J., Elzinga, P., Viaene, S., Van Hulle, M. & Dedene G. (2009). Gaining insight in domestic violence with emergent self organizing maps, *Expert systems with applications*, 36, (9), 11864 – 11874.



Use Case 1 example in Police Case: Discovery of profile of 'loverboy'...





Formal Concept Analysis Use case 2...

IDENTIFY Potential Value Leaks in the Process

- Investigate the Process for 'not-normal' form (e.g. focus on many-to-many transitions).
- Obtain normalized Process forms by means of Process Discovery (FCA on Process Logging Data).
- Investigate the non-normalized transitions in terms of service/information imperfections and Value Leaks.

Dedene G., Warnar R., Peters E., Viaene S., Mercado C. (2015), Assessing the Value of Process Improvement by means of Service Imperfections and Value Leaks: The case of a large scale Municipality Contact Center, *accepted for INFORMS SERVICE SCIENCE 2015*.



Formal Concept Analysis Use case 3...

- Construct and validate large scale concept models by combining FCA and Unified Modeling (UML) for Business Verticals (such as parking).
- So far, conceptual modeling for mobility/parking has not been applied yet extensively, because of the complexity of the Business. FCA provides now a scalable solution !

Chang J., Fong-Gee Y. (2012), Information analysis of maintenance and rehabilitation activities for a road system using formal concept analysis (FCA), ISCCBE 14th International Conference on Computing in Civil and Building Engineering, Moscow, Russia, 2012

- The discovered models are scalable, consistent and automatically in normal form...



ANY QUESTIONS...?