Acyclic Type-of-Relationship Problems on the Internet: An Experimental Analysis

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Details

- Hummel, Kosub: *Acyclic Type-of-Relationship Problems on the Internet: An Experimental Analysis*
- The same as (more detailed) technical report
- Theoretical foundation:
  Kosub, Maaß, Täubig: *Acyclic Type-of-Relationship Problems on the Internet*

Here simplified version:
only customer-provider relationships

The problem

Given *AS paths* from publicly available routing tables, determine the *business relationships* between the ASes.

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BGP business relationships allow the inference of BGP policies and serve as input to

- BGP simulation
- analysis of BGP instabilities
- optimizing Internet operation
- business decisions
- ...

General Approach

Start from AS path set

- AS1, AS2, AS3, AS4
- AS5, AS2, AS3

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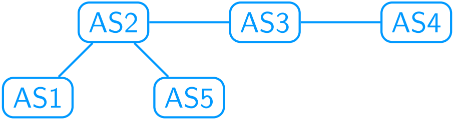
Construct AS graph



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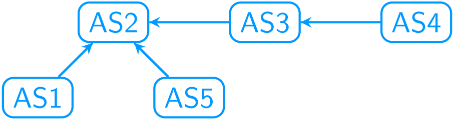
Construct AS graph and find orientation



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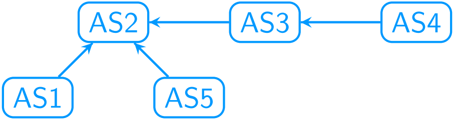

Orientation can be carried over to paths

- AS1 $\rightarrow$ AS2 $\leftarrow$ AS3 $\leftarrow$ AS4
- AS5 $\rightarrow$ AS2 $\leftarrow$ AS3

How to find the orientation?

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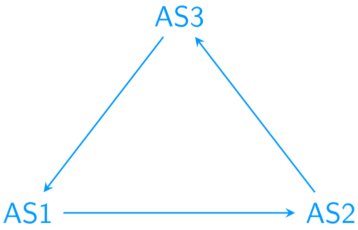
Problem solved by "traditional" algorithms:
Find an orientation of the edges,
such that no path contains the pattern $\leftarrow \rightarrow$

Is this a valid orientation?

AS1 → AS2 → AS3
AS3 → AS1 → AS2



If one of these ASes cancels its contract, it still has full connectivity!

Acyclic Inference

New problem:
Orient graph such that valley-freeness is respected *and* the graph is acyclic

- can be solved efficiently (similar to finding a topological sort)
- real instances are unsolvable ($\Rightarrow$ minimize violations heuristically)
- Additional benefit: can deal with (verified) pre-knowledge

Experimental Comparison of Algorithms

- Gao
- Derandomised approximation algorithm (APX)
- Combinatorial/2-SAT (DPP*)
- Acyclic heuristic (AHeu)

Data used for Comparison

From publicly available routing tables:

- 2 002 680 AS paths (average length 3.43)
- containing 21 862 ASes (56 922 AS pairs)

From WHOIS (RPSL) and BGP communities attribute:

- 2 739 customer-to-provider edges
- graph only consisting of reference edges is *acyclic*!

Experimental Results

Algorithm	Invalid paths	Misclassified c-to-p for reliable edge set
Gao	27.366% (249 not valley-free) (547811 with s-to-s edge)	1.387% (4 as p-to-c) (34 as s-to-s)
APX	4.483% (89775 not valley-free)	5.330% (146 as p-to-c)
DPP*	0.519% (10391 not valley-free)	0.913% (25 as p-to-c)
AHeu ($W = 10$)	0.483% (9666 not valley-free)	0.292% (8 as p-to-c)

Conclusion

- The Internet hierarchy seems to be acyclic ...
- ... so *acyclicity* should be respected when solving the ToR problem
- ... and maybe also for other algorithms/applications

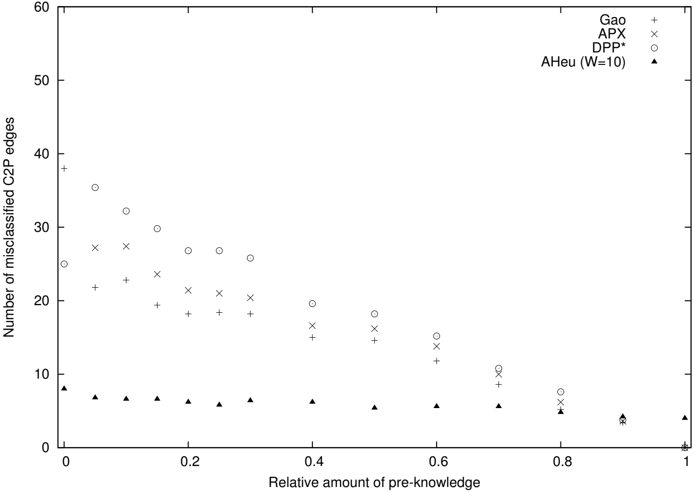
Thanks!

Questions?

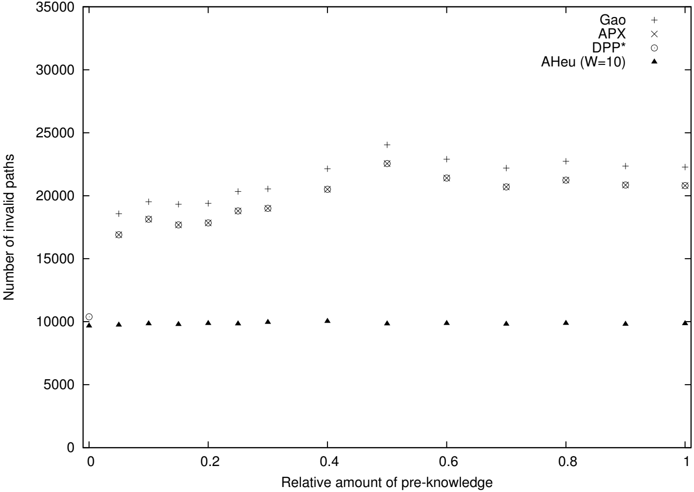
Data & Code:
`http://www14.in.tum.de/software/BGP/hummel-kosub-07.html`

Email: {hummelb, kosub}@in.tum.de

Using Pre-Knowledge (1)

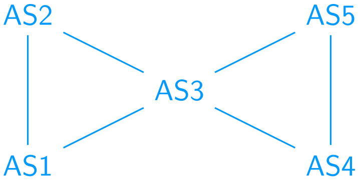


Pre-Knowledge (2)



Example: Acyclic Inference Algorithm

Pfad 1: AS2 – AS1 – AS3 – AS5 – AS4
Pfad 2: AS1 – AS2 – AS3 – AS4



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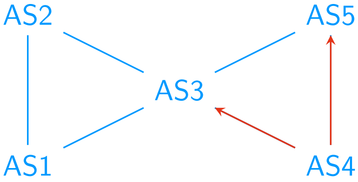

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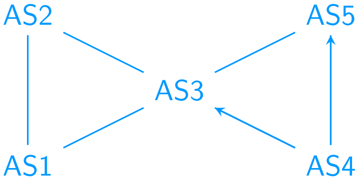

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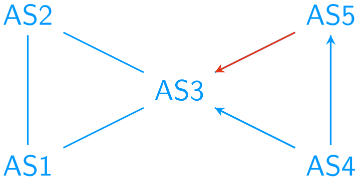

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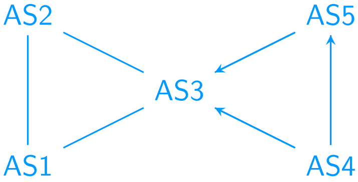

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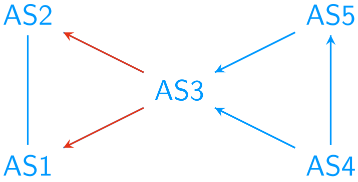

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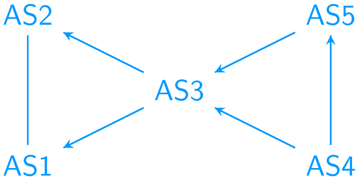

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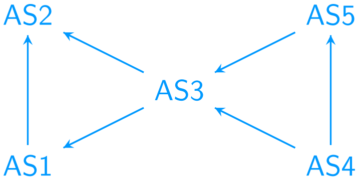

Example: Unsolvable Instance

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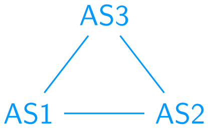

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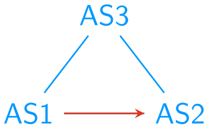

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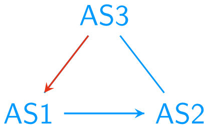

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