Combining Heuristics for Configuration Problems using ASP

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Outline

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- Motivation
- Combined Configuration Problem (CCP)
- Solving framework for the CCP
- Heuristic approaches
- Benchmarks
- Evaluation
- Summary

Research projects

RECONCILE *(Reconciling Legacy Instances with changed Ontologies):* 01.06.2010 – 31.05.2013

HINT (*Heuristic Intelligence):* 01.06.2013 – 31.05.2016

AINF and Cognitive Psychology Unit

Reconcile results

Use cases: Partner Units Problem [Aschinger et al. 2011], House problem (Rack configuration) [Friedrich et al. 2011], Reviewer Assignment Problem [Ryabokon et at. 2012]

http://isbi.aau.at/reconcile/benchmarks

Approaches:

- Answer set programming and SAT
- Constraint programming
- Object-oriented programming
- Integer programming

Configuration problem is too hard! (without heuristics)

[Teppan et al. 2012], [Ryabokon et al. 2013]

HINT goals

"Development of new methods for the efficient generation of heuristics" http://isbi.aau.at/hint/

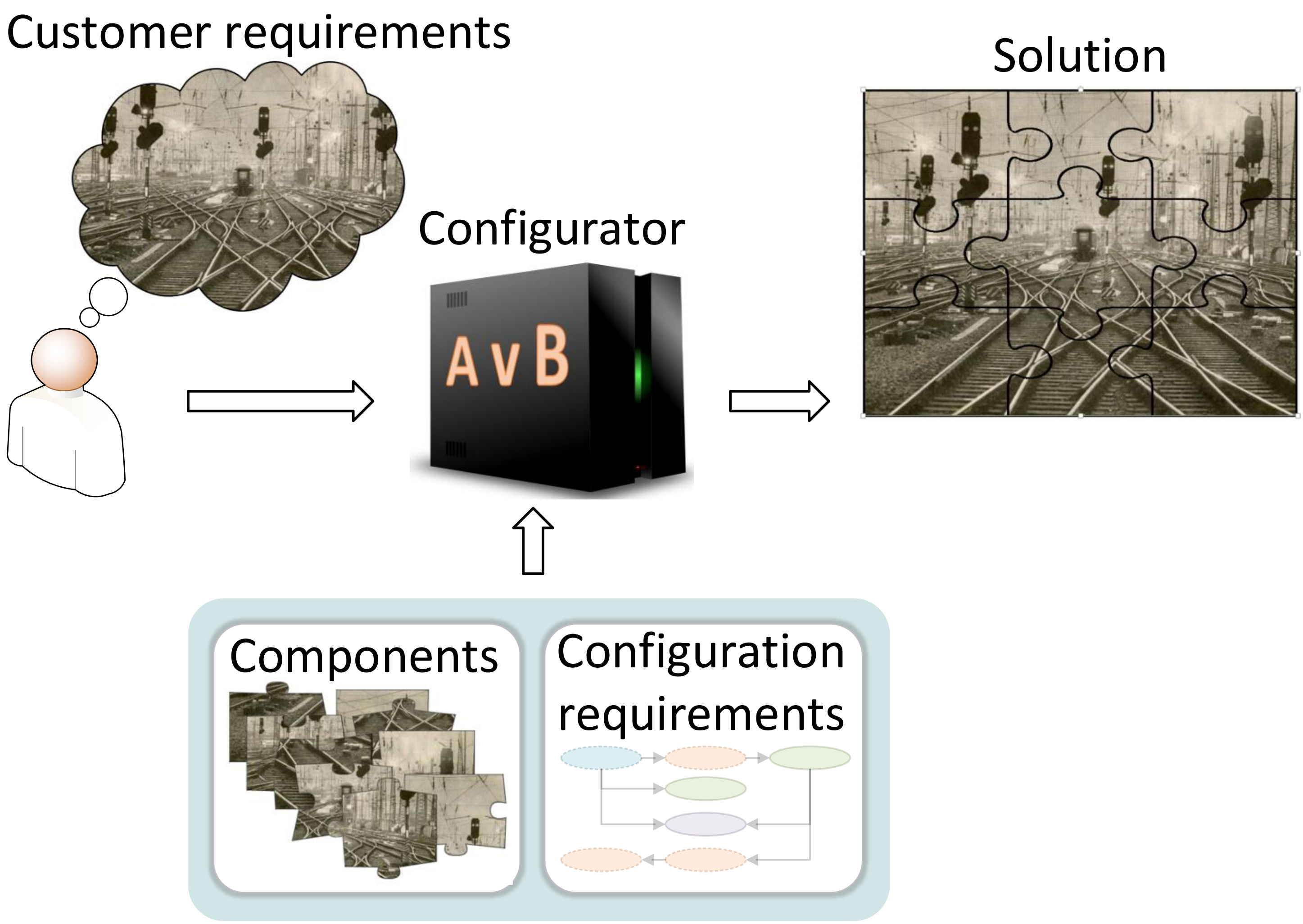
- Identify promising domain-specific heuristics and express them within general purpose framework
- Combine different heuristics for different problems
- Create new heuristics out of existing ones

create + adapt + evolve heuristics

=

Heuristic INTelligence

Configuration problem



CCP instance

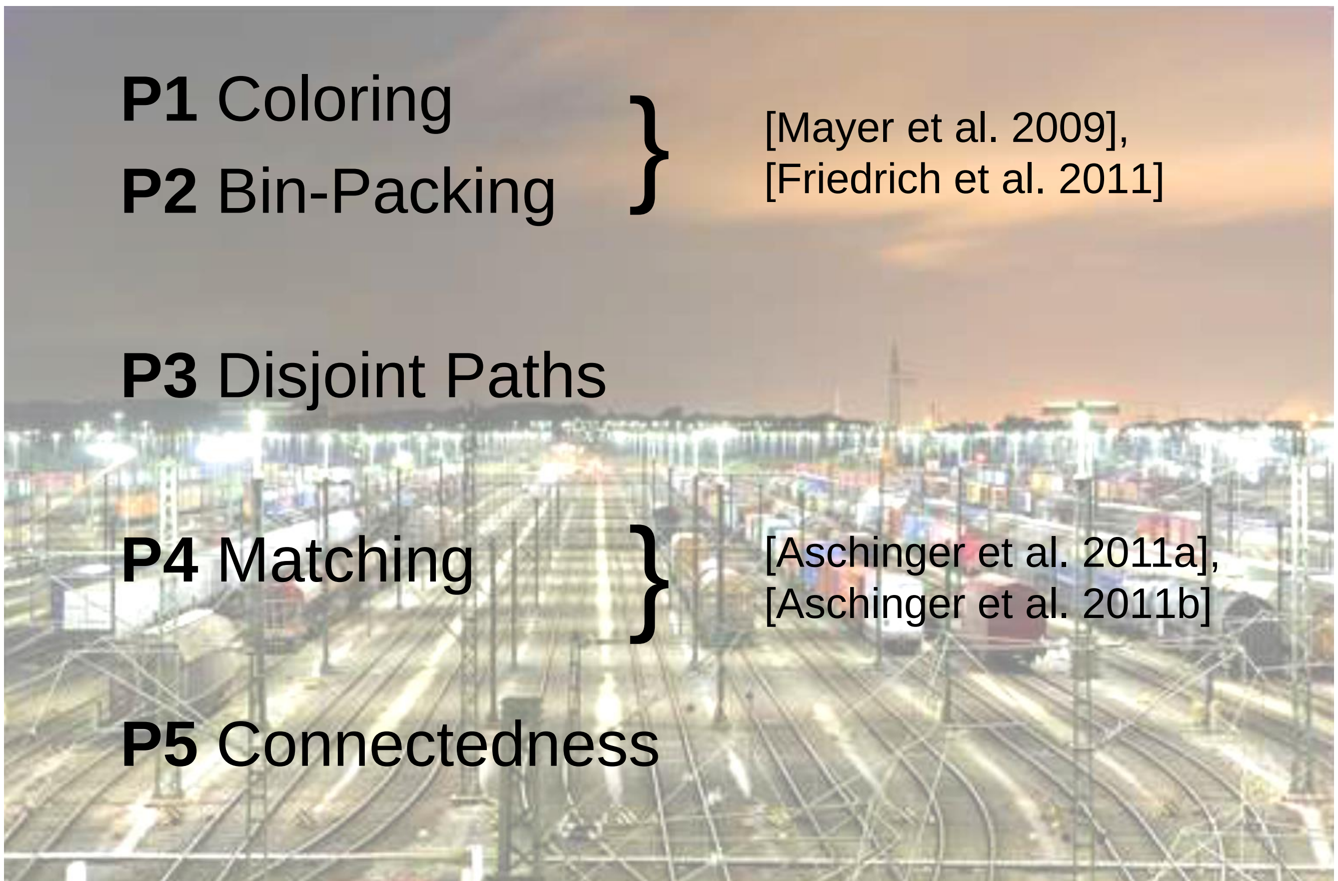
- A directed acyclic graph (edges, vertices)
- Type and size of a vertex
- Sets of vertices denoting paths in the graph
- Set of areas and their possible border elements
- Maximal number of selected border elements
- Number of available colors
- Number of bins and their capacity

Benchmarks

Instance	Vertices	Colors	Bins	MaxBinCapacity	MaxBorder
tg_001004	1004	58	4	20	2

Combined Configuration Problem

Given a CCP instance, solve the following problems separately or in combinations:



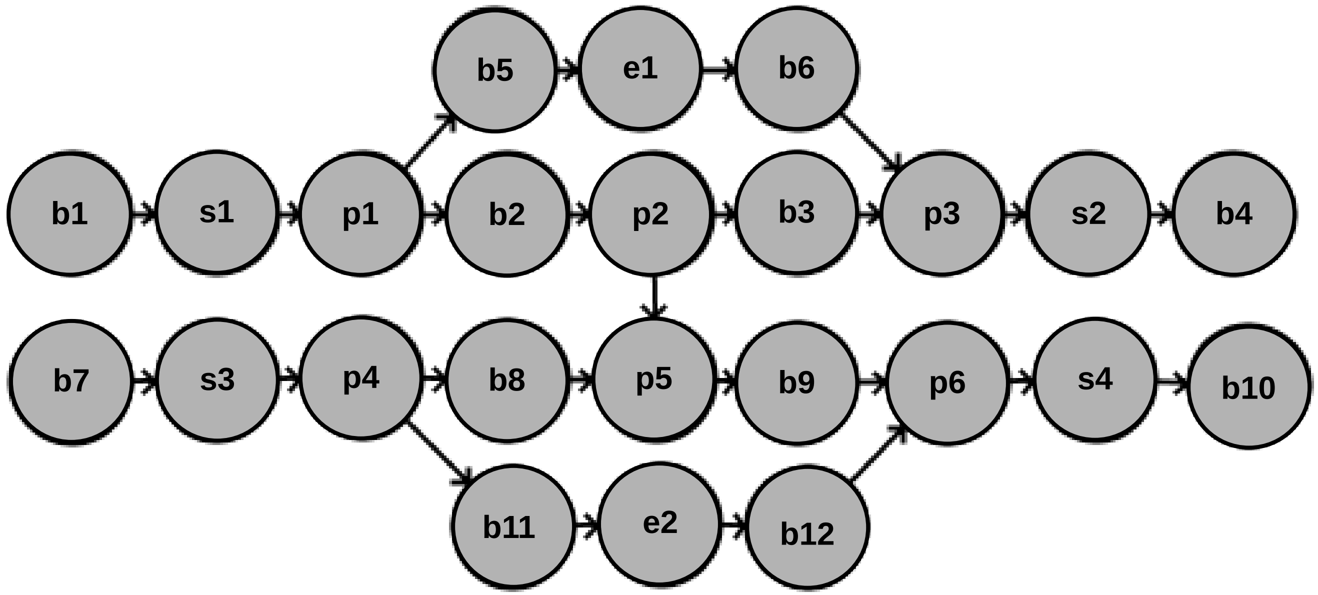
P1 Coloring
P2 Bin-Packing
} [Mayer et al. 2009], [Friedrich et al. 2011]

P3 Disjoint Paths

P4 Matching
} [Aschinger et al. 2011a], [Aschinger et al. 2011b]

P5 Connectedness

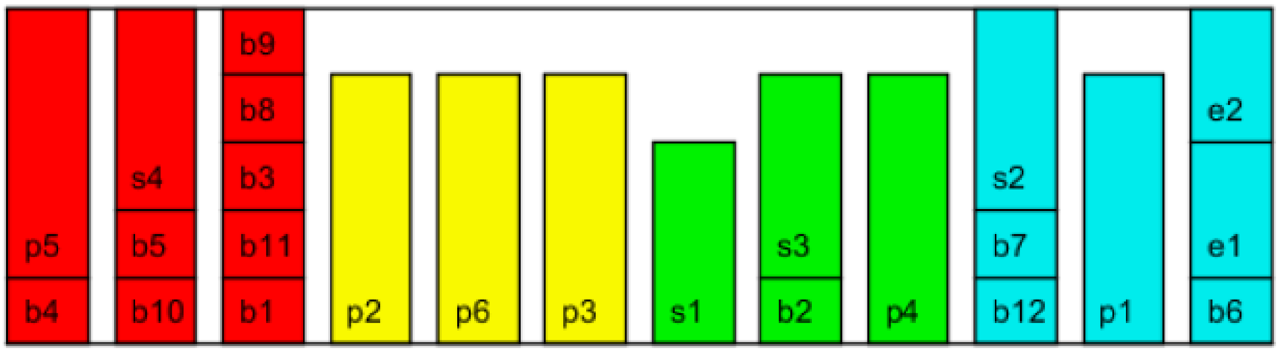
Coloring (P1)



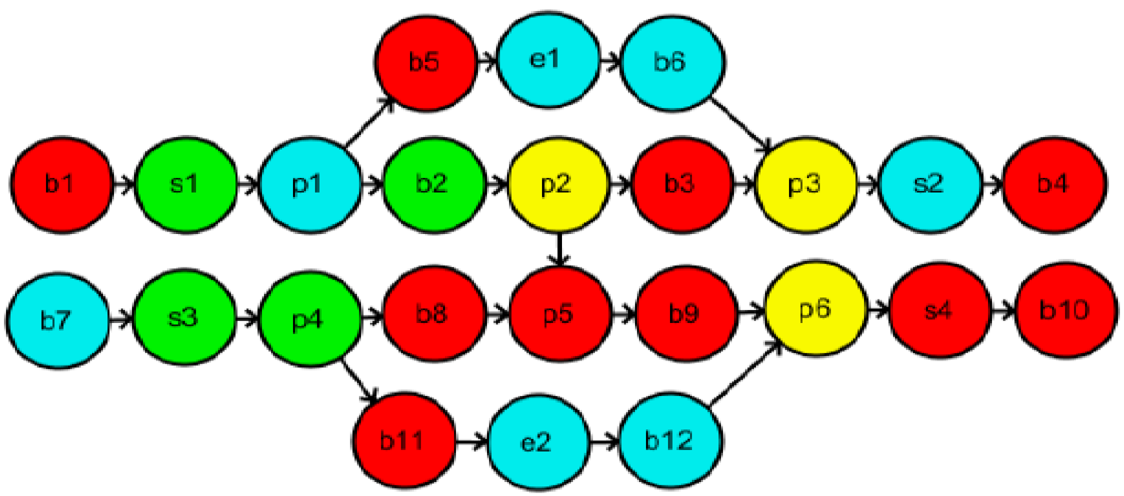
b5
e1
b6
b1
s1
p1
b2
p2
b3
p3
s2
b4
b7
s3
p4
b8
p5
b9
p6
s4
b10
b11
e2
b12

Bin-Packing (P2)

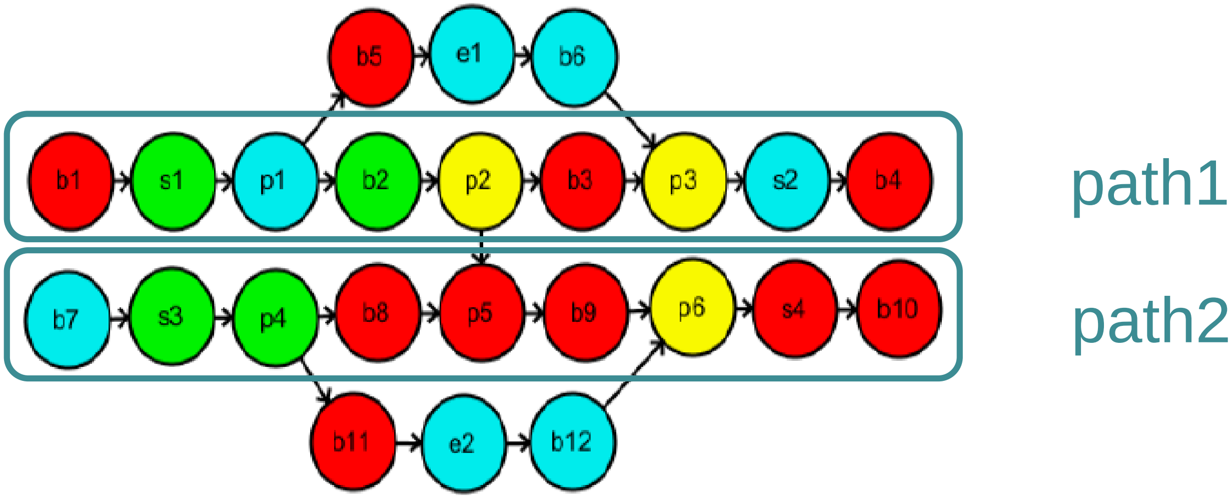
Bin capacity = 5

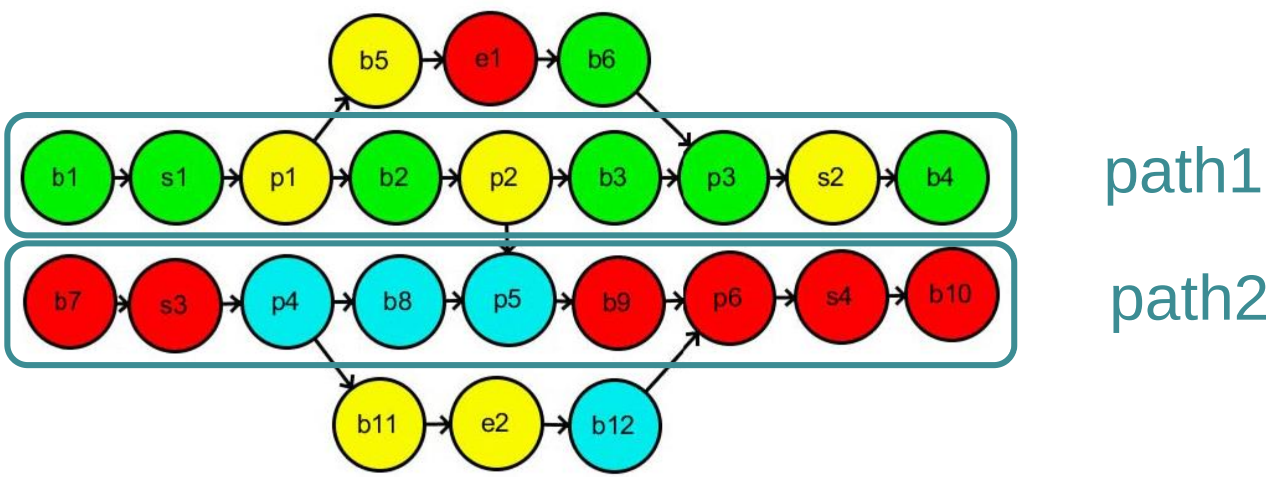


Vertex	Size
b	1
e	2
s	3
p	4

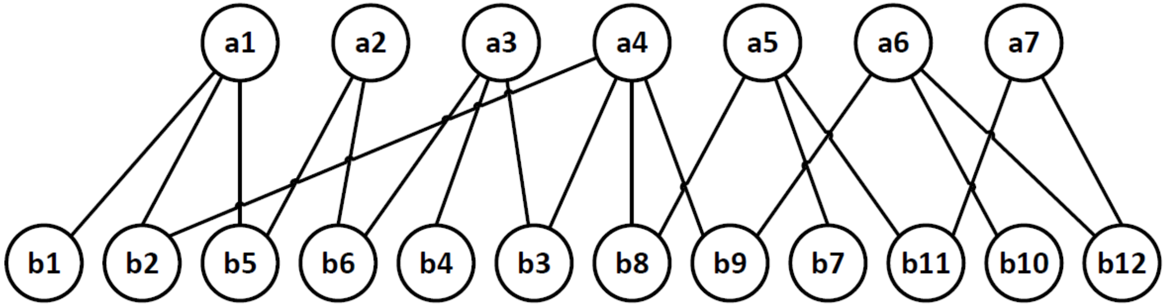


Disjoint Paths (P3)

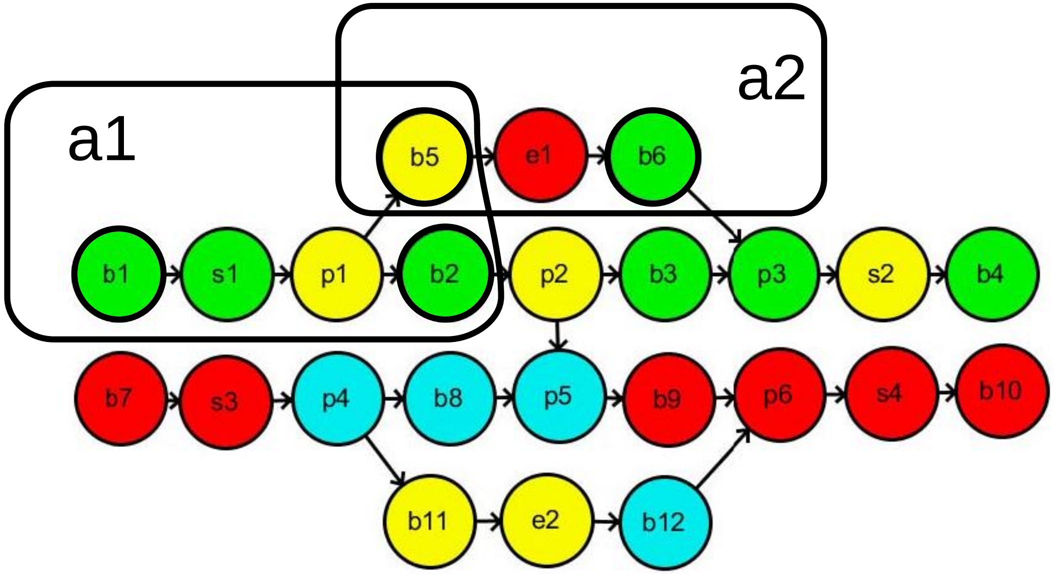




Matching requirements (P4)



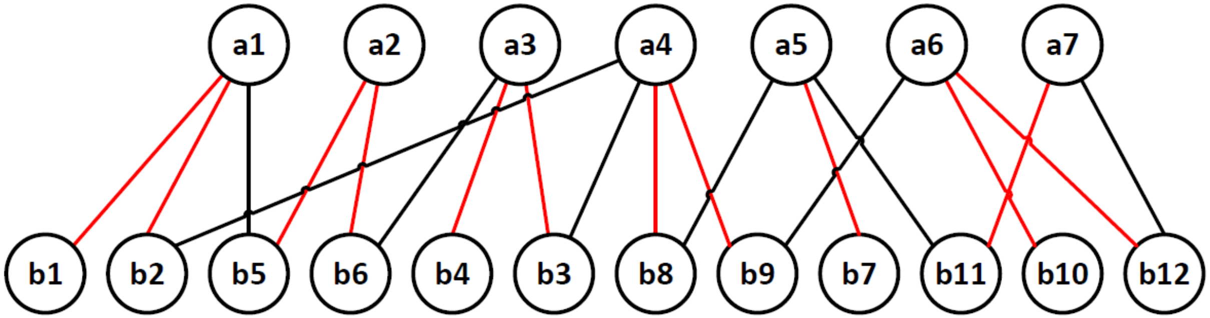
Each area can have at most 2 border elements



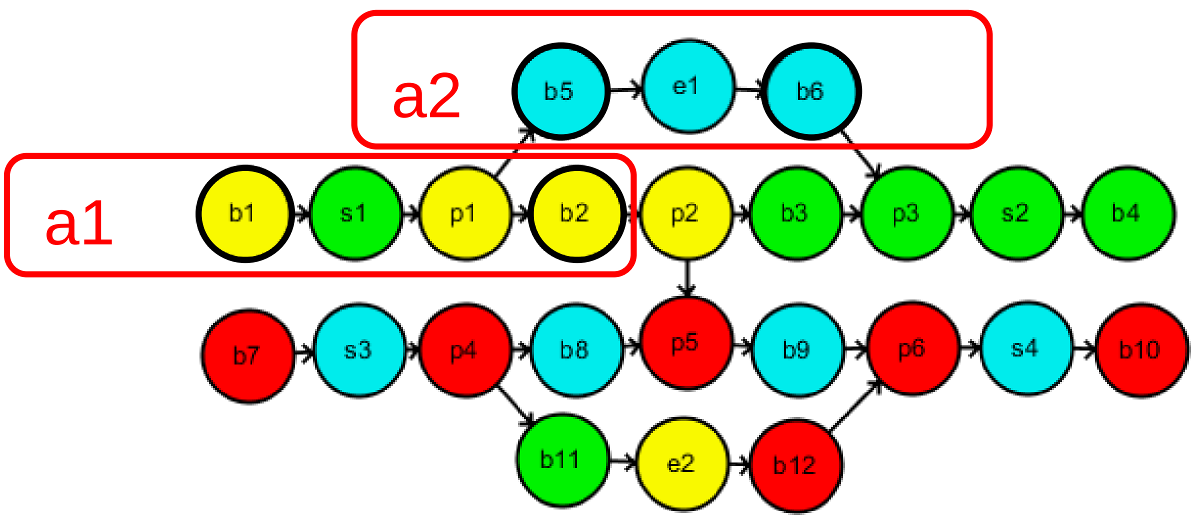
The selected border elements of an area must have the same color

Matching solution (P4)

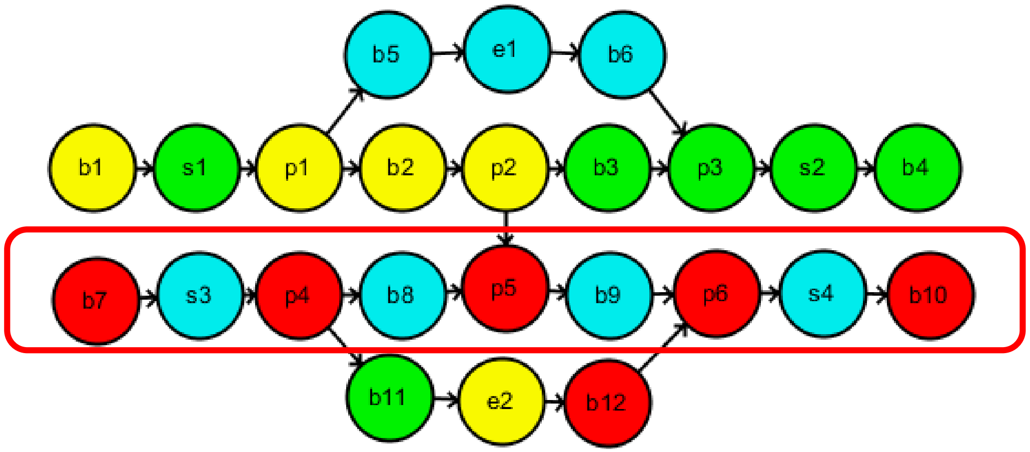
Each area has at most 2 border elements

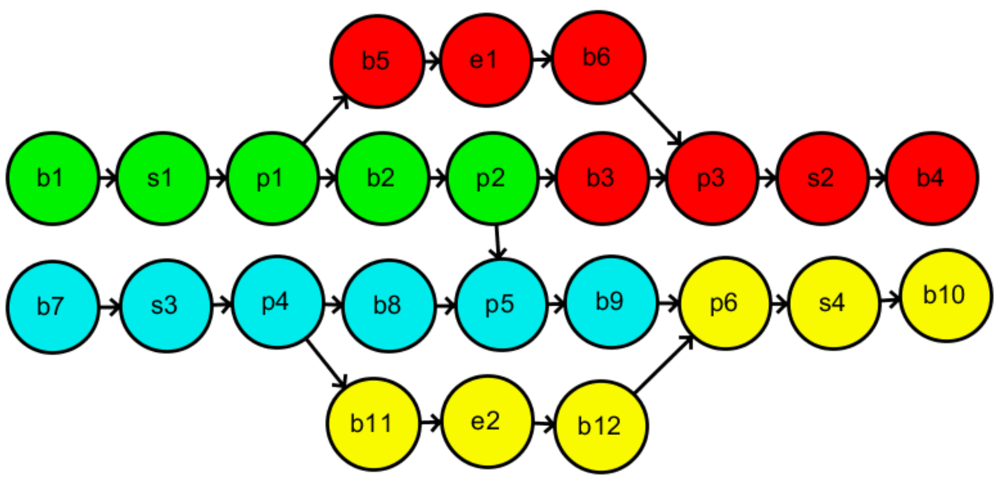


The selected border elements of an area have the same color

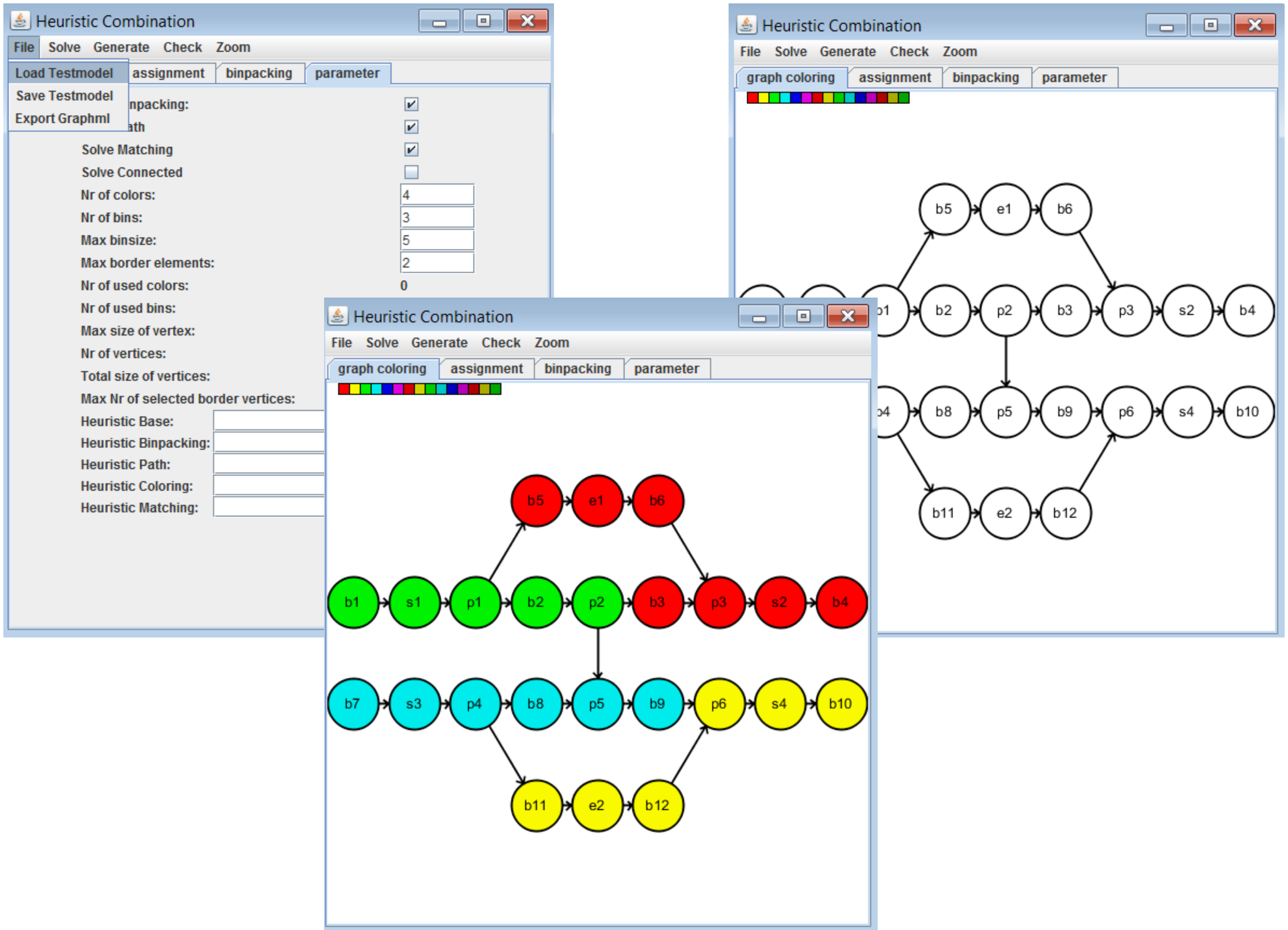


Connectedness (P5)





Solving framework



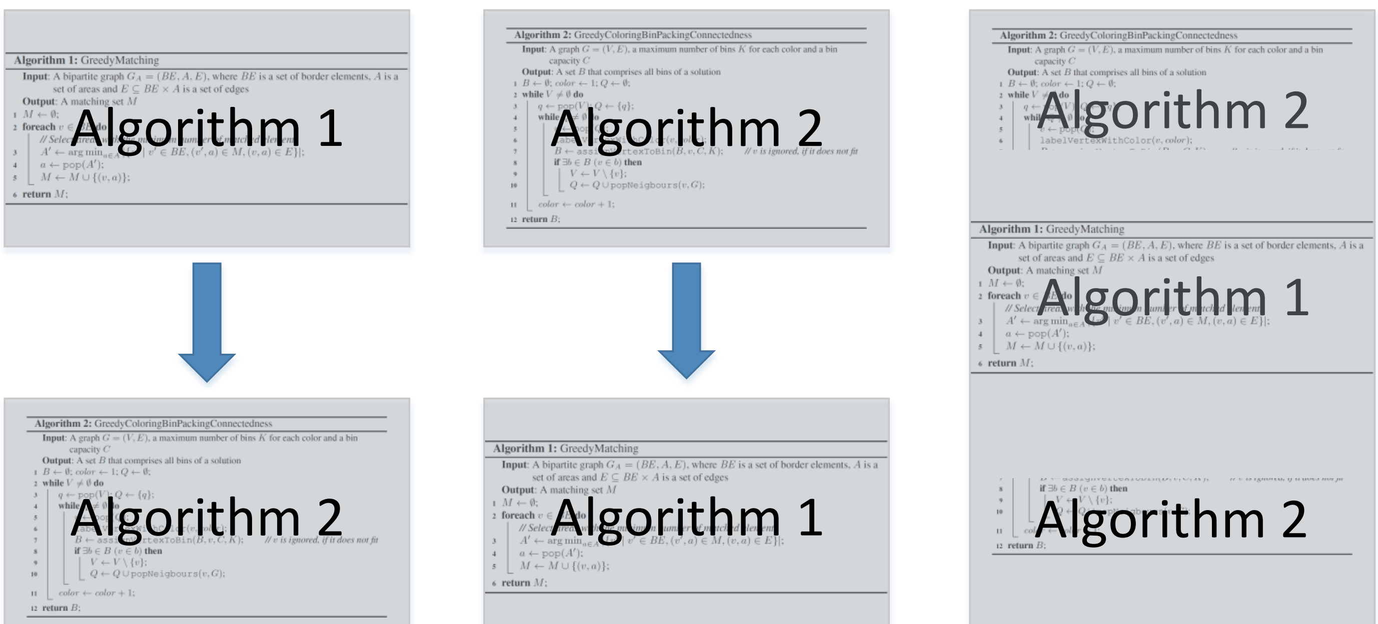
CCP greedy algorithms

Algorithm 1: Matching (P4)

For each border element select an area with the minimum number of already matched elements

Algorithm 2: Coloring_Bin-Packing_Connectedness (P1, P2, P5)

Select a subset of connected vertices, color them with a selected color and place them to bins. Change the color and repeat until all vertices are processed



Heuristics in ASP

Gebser et al., *Domain-specific Heuristics in ASP*. AAAI 2013.

- Specified using atoms `_heuristic(a,m,v,p)`
- Shortcuts are used, e.g. `_heuristic(a,true,v)`
- Configuration example:

```
size(a,1). size(b,2). size(c,3).
1 {selected(V,S): size(V,S)} 1.
_heuristic(selected(V,S), true, S) :- size(V,S).
```

⇩

```
size(a,1). size(b,2). size(c,3).
1<={selected(a,1), selected(b,2), selected(c,3)}<=1.
_heuristic(selected(a,1),true,1). heuristic(selected(b,2),true,2).
_heuristic(selected(c,3),true,3).
```

⇩

`selected(c,3)` …

Greedy vs. ASP

Greedy

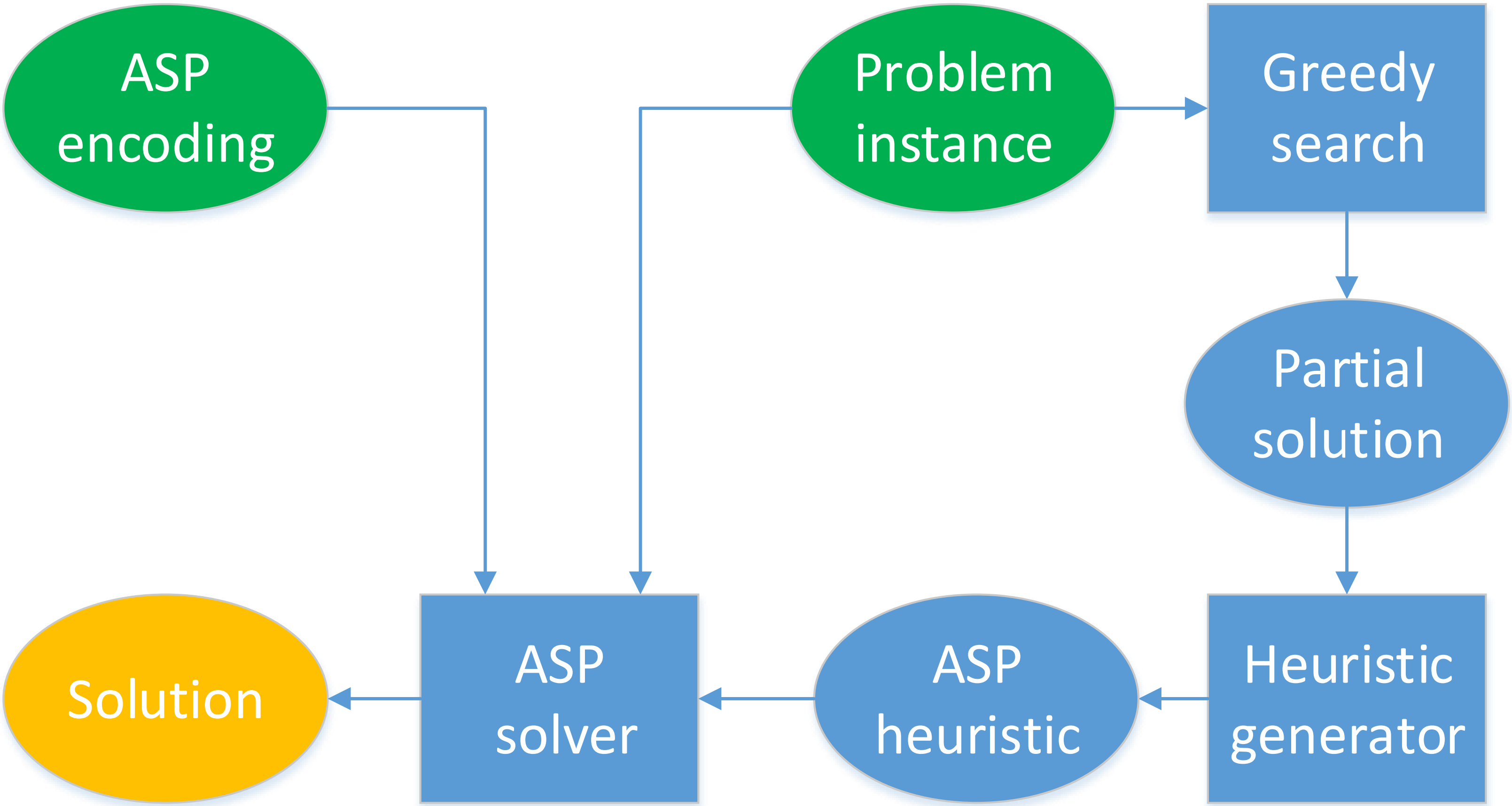
- ☺ An implementation of a subproblem of the CCP can be done easy and is usually efficient
- ☹ Designing a mixed greedy method for the problem is difficult

ASP

- ☺ The addition of requirements in ASP is just a matter of adding some rules to an encoding
- ☹ Generation of heuristics is “expensive”

Combine two “worlds” effectivelly!

Greedy & ASP architecture



Benchmarks

Set 1:

Bin-Packing instances converted to the CCP instances

http://www.wiwi.uni-jena.de/Entscheidung/binpp/index.htm

Set 2 and Set 3:

- Moderate and hard CCP instances derived from Siemens configurations
- Available from http://isbi.aau.at/hint/problems
- Submitted to the ASP competition 2015
  http://aspcomp2015.dibris.unige.it/

Evaluation*

- Experiment 1:
  - Instances Set 1
  - P2 (Bin-Packing) must be solved
  - Plain ASP encoding vs. ASP encodings extended with the BPP heuristics (FF(D), BF(D) and NF(D))
  - FF(D) is on average 2.5 times faster, less bins are utilized

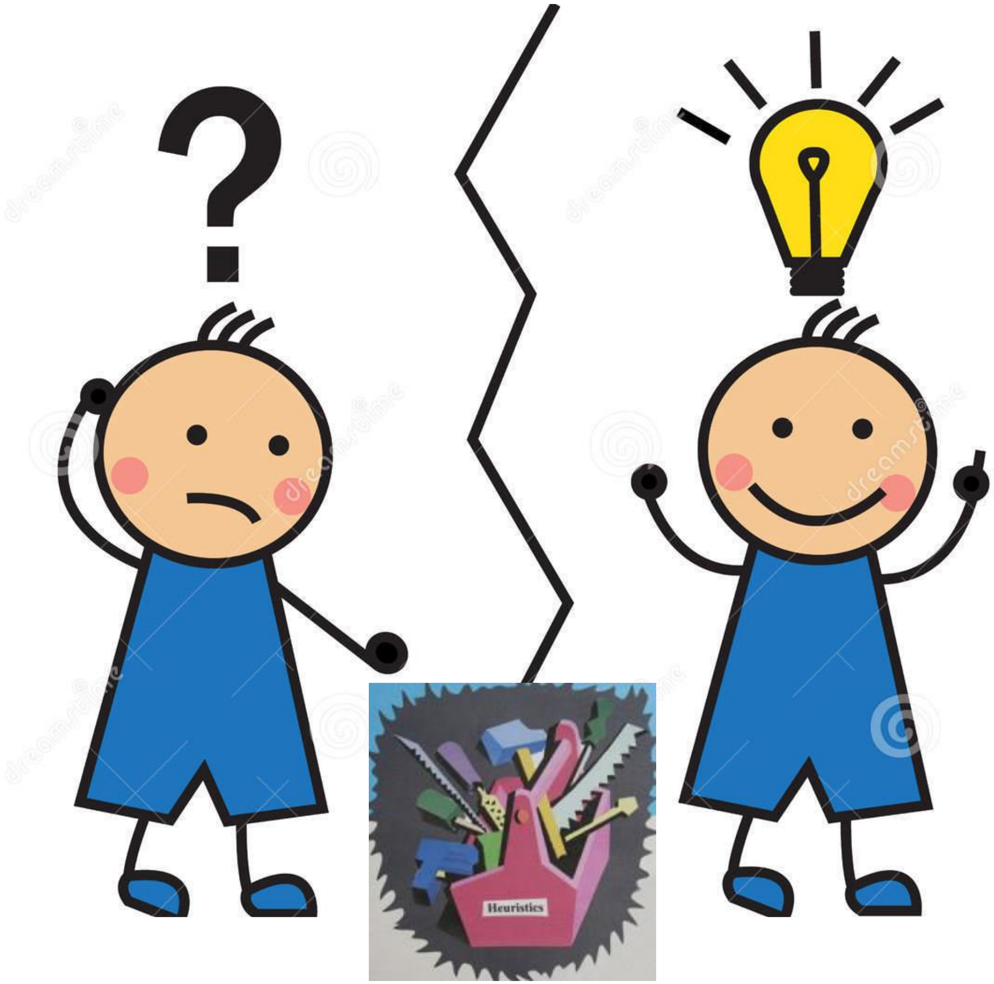
- Experiment 2 and Experiment 3:
  - Instances Set 2 and instances Set 3 resp.
  - P1 - P5 (all subproblems) must be solved
  - Plain ASP encoding vs. Greedy & ASP approach
  - Combined approach outperforms Plain ASP encoding, the quality of solutions is the same

* Gringo 4.4.0, Clasp 3.0.5; Intel i7-3930K CPU (3.20GHz), 64 GB RAM, timeout 900 sec

Summary

- Heuristic greedy algorithms can find a solution faster, but the design of such algorithms is complicated
- ASP allows for combination of requirements in an easier way, but has performance issues
- Combining different solving methods is possible and seems to be promising!
- ~50% more instances can be solved
- up to 18 times faster on average
- Next steps…

Thank you! Questions?



The images are taken from: http://psychstrike.com/ and http://www.dreamstime.com/