ALPEN-ADRIA UNIVERSITÄT KLAGENFURT | WIEN GRAZ

Solving Combined Configuration Problems: A Heuristic Approach

Martin Gebser,
Aalto University, HIIT, Finland and Potsdam University, Germany

Anna Ryabokon,
Alpen-Adria-Universität Klagenfurt, Austria

Gottfried Schenner,
Siemens AG Österreich, Austria

funded by FFG, COIN and AoF (grants 840242 and 251170)

Outline

- 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, House problem (Rack configuration), Reviewer Assignment Problem

Approaches [Aschinger et al. 2011], [Friedrich et al. 2011], [Ryabokon et at. 2012], [Teppan et al. 2012], [Ryabokon et al. 2013], [Ryabokon 2015]:

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

Configuration problem is too hard! (without heuristics)

- different approaches have different issues

HINT goals

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

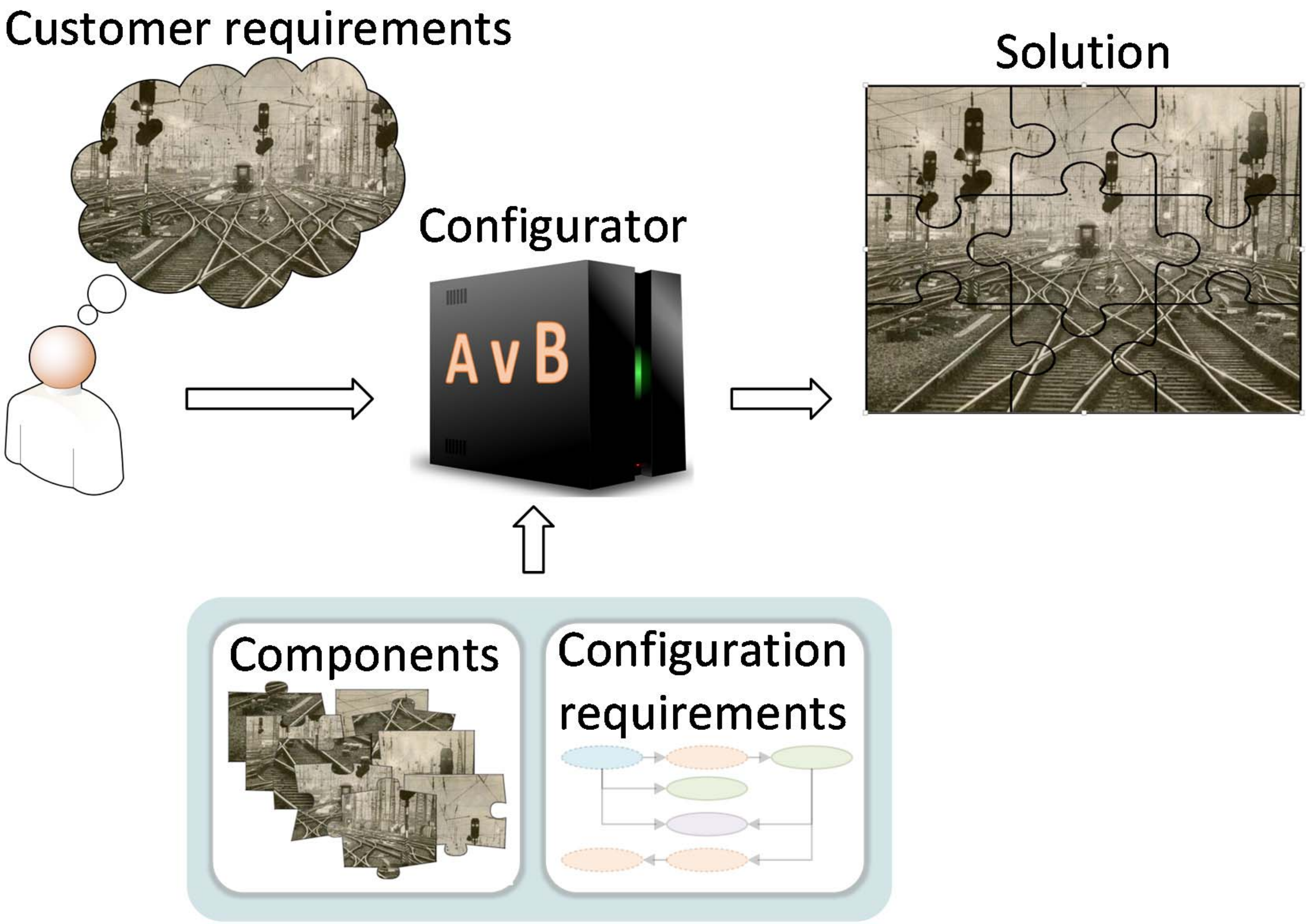
- Identify promising domain-specific heuristics and express them within general purpose framework
- Combine different heuristics for different problems
- Create new heuristics out of existing ones

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]

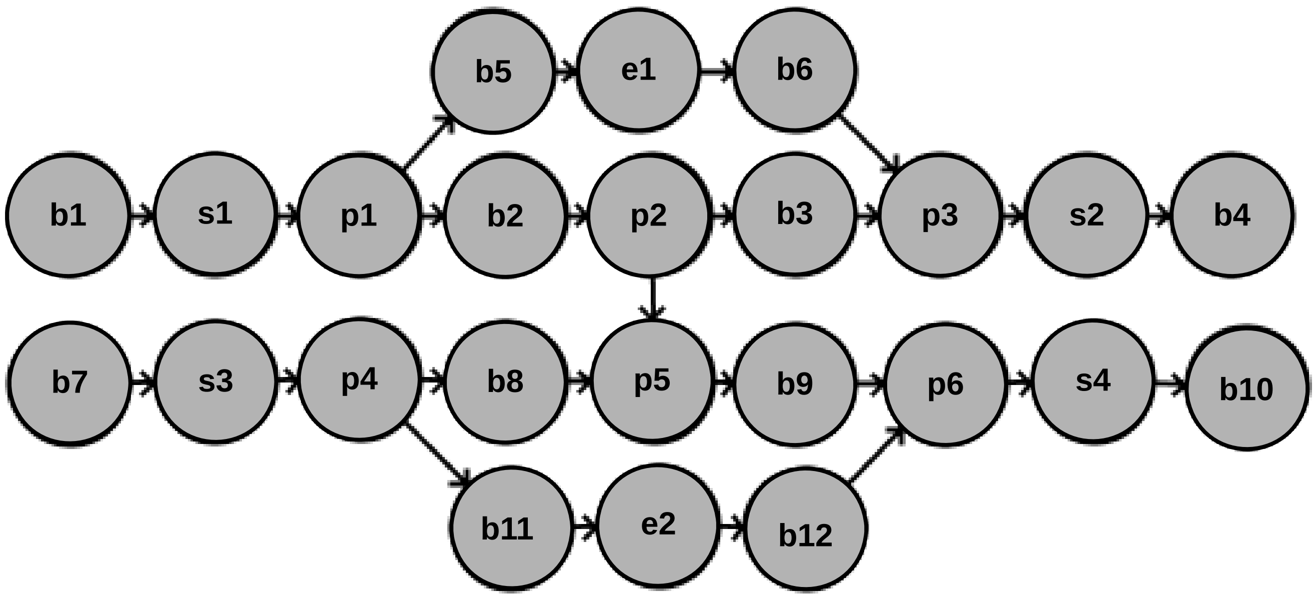
P3 Disjoint Paths

P4 Matching

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

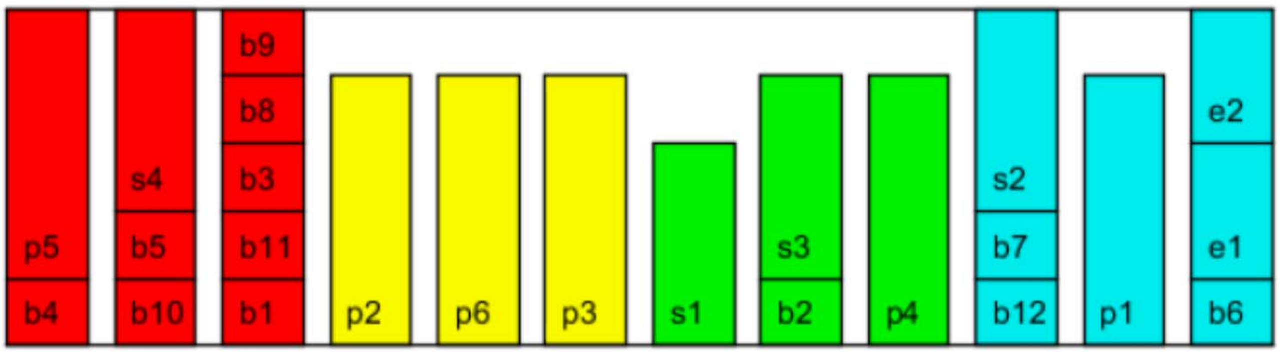
P5 Connectedness

Coloring (P1)

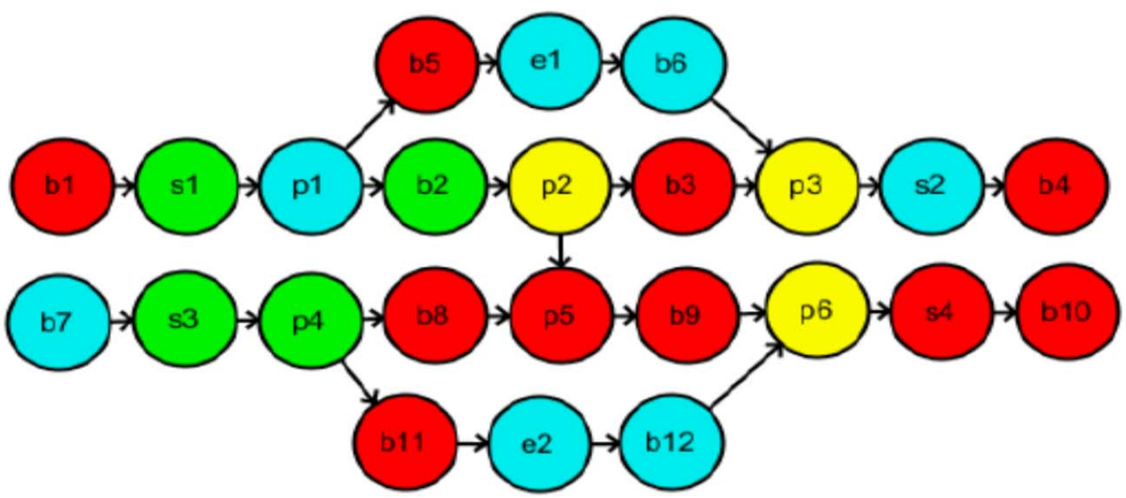

b5
e1
b6
b1
s1
p1
b2
p2
b3
p3
s2
b4
b7
s3
p4
b8
p5
b9
p6
s4
b10
b11
e2
b12

Bin-Packing (P2)

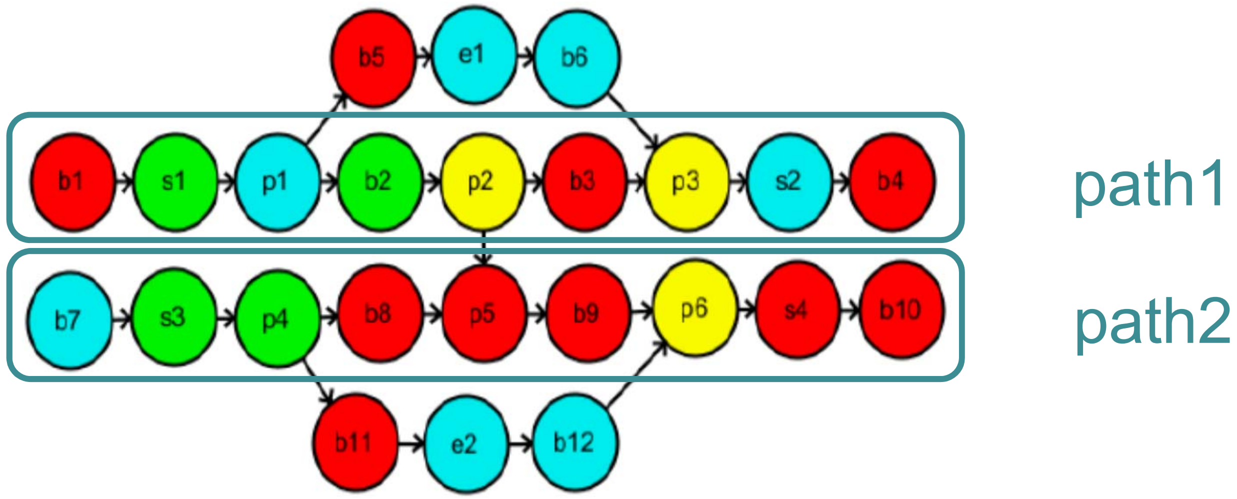
Bin capacity = 5

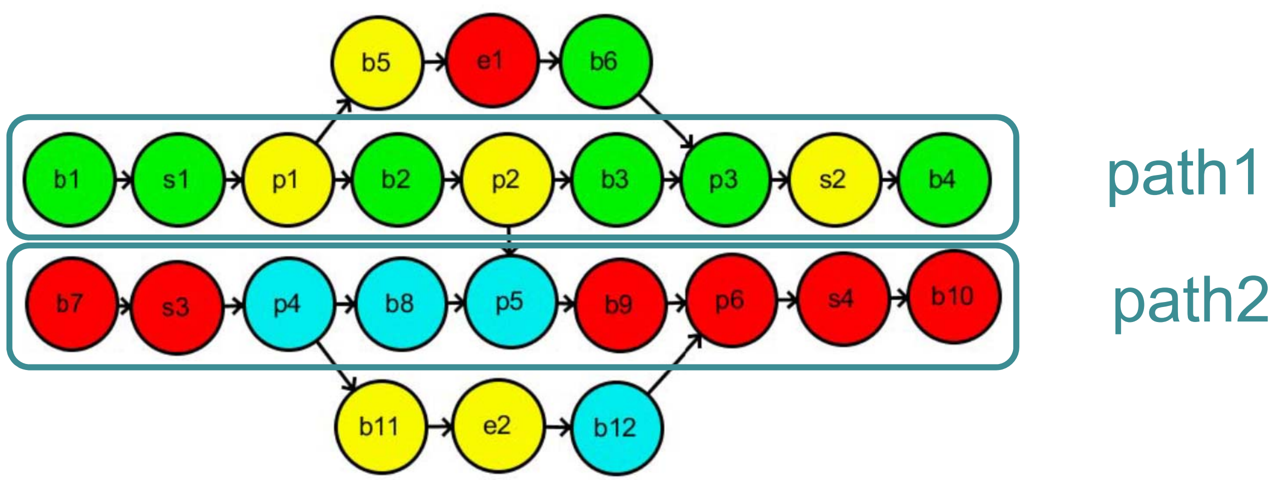


Vertex	Size
b	1
e	2
s	3
p	4

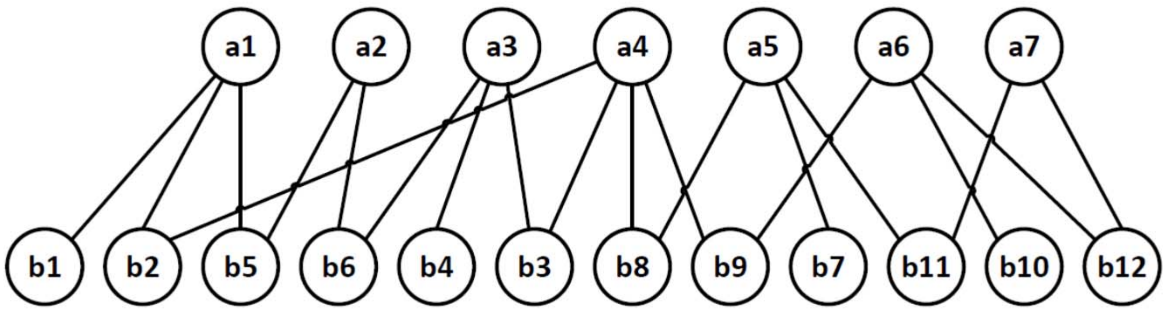


Disjoint Paths (P3)

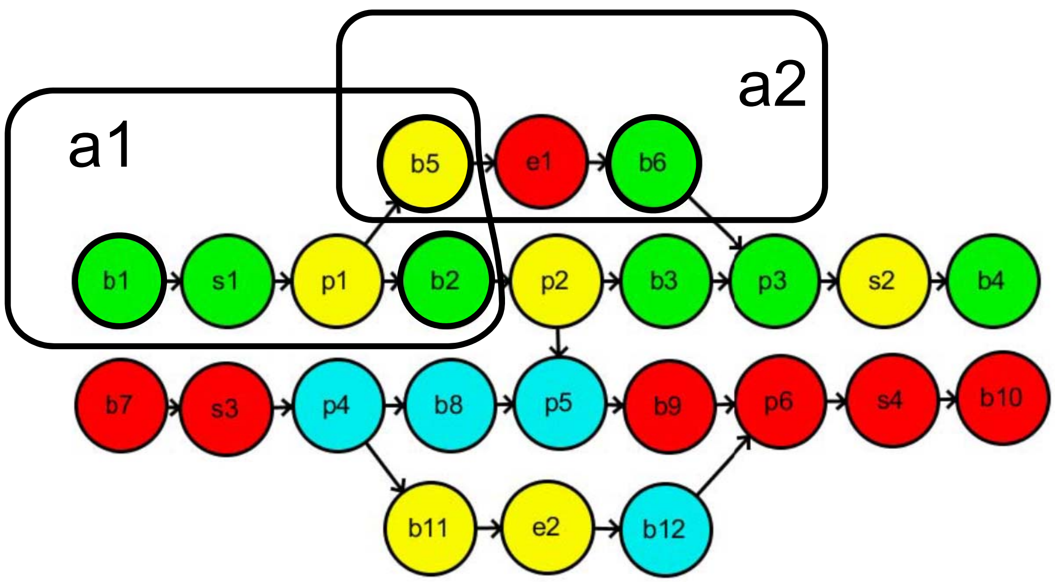




Matching requirements (P4)



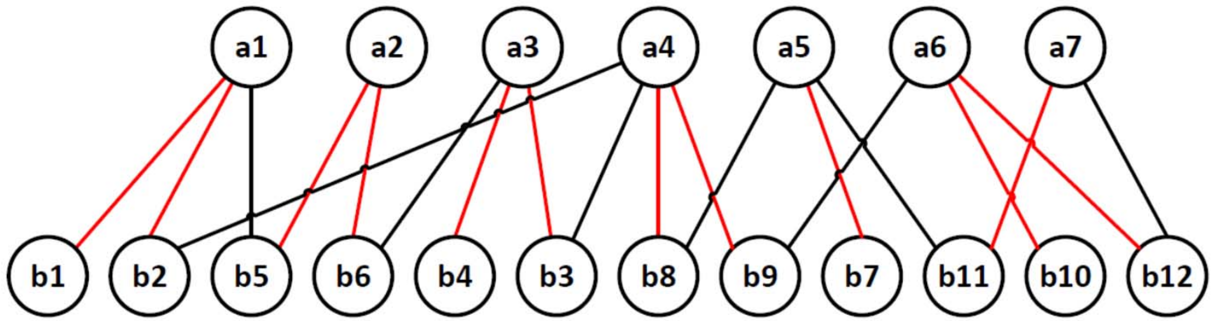
Each area can have at most 2 border elements



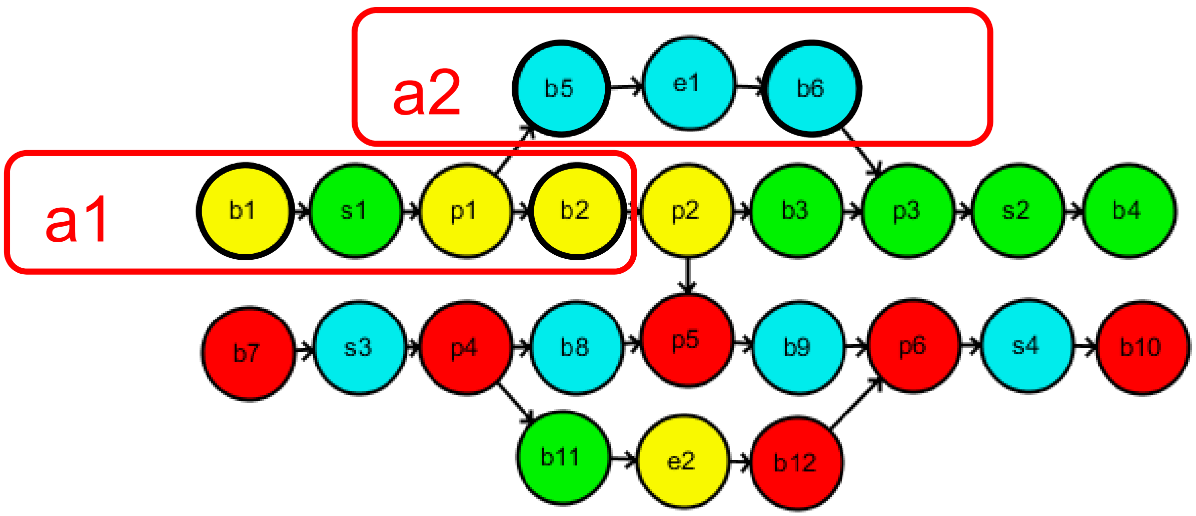
The selected border elements of an area must have the same color

Matching solution (P4)

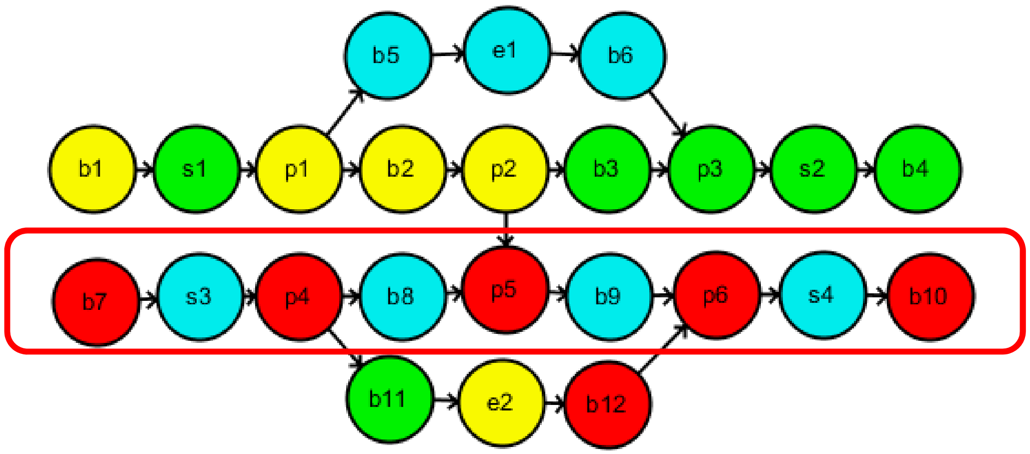
Each area has at most 2 border elements

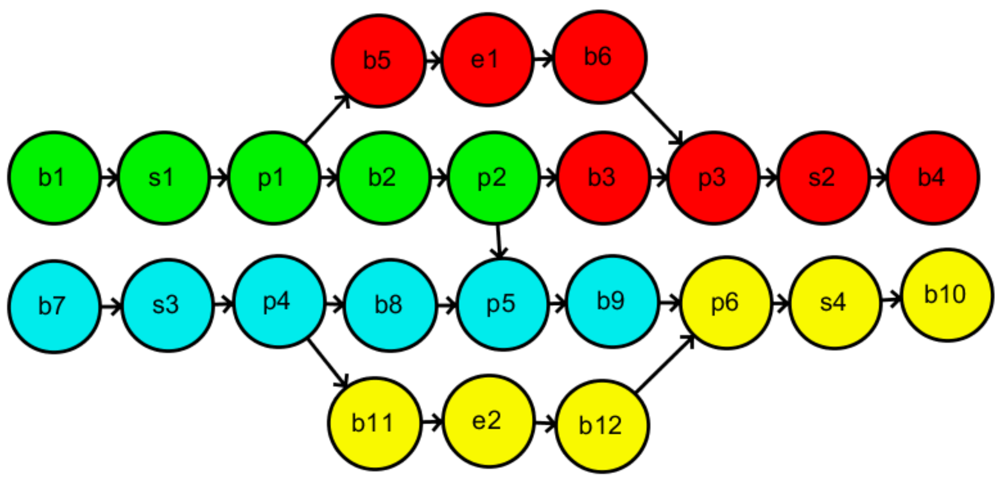


The selected border elements of an area have the same color

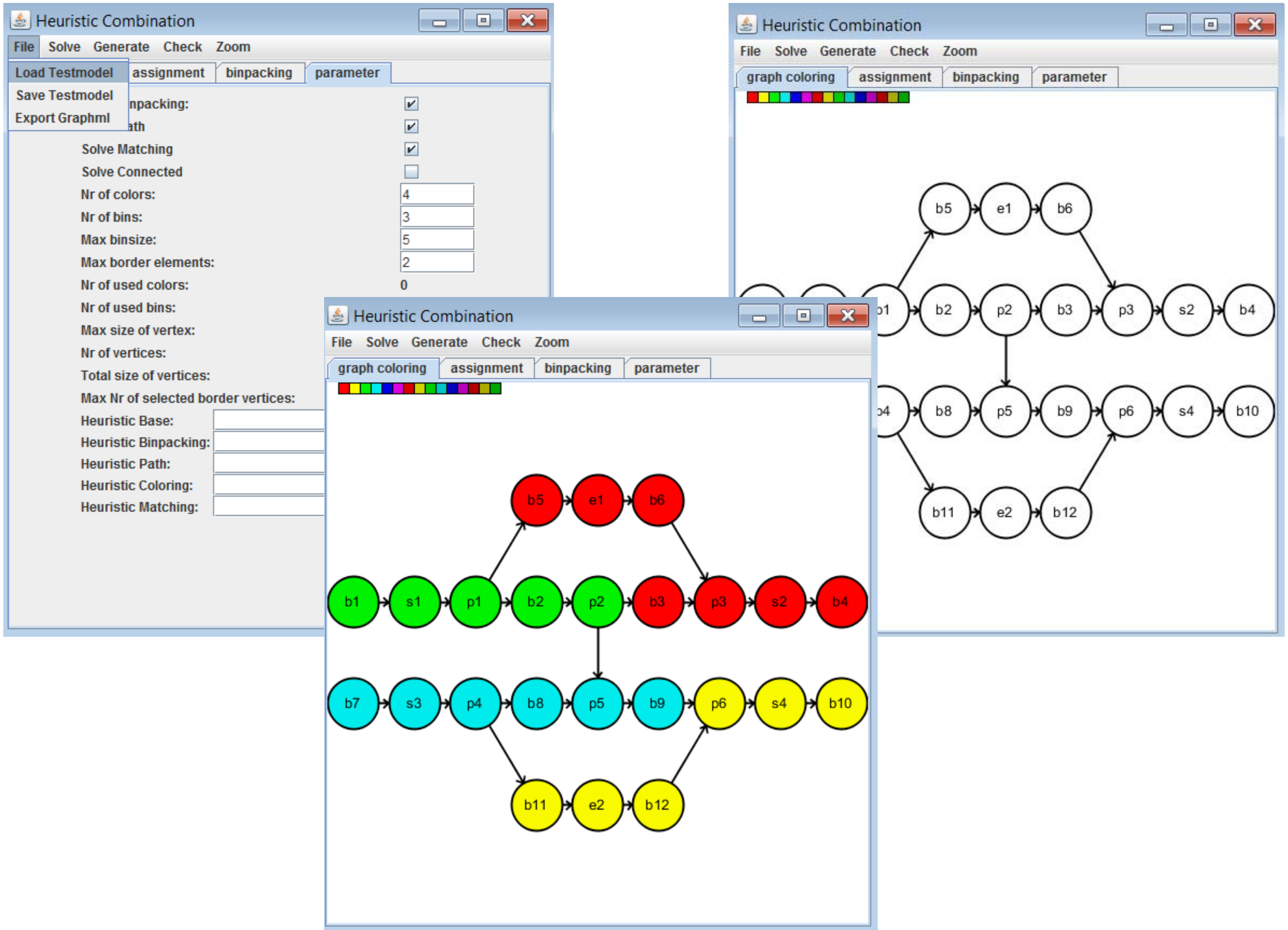


Connectedness (P5)





Solving framework



Greedy Search

- Locally best decisions according to a heuristic
- Incomplete and do not guarantee optimality
- Fast computation of a solution

CCP greedy algorithms:

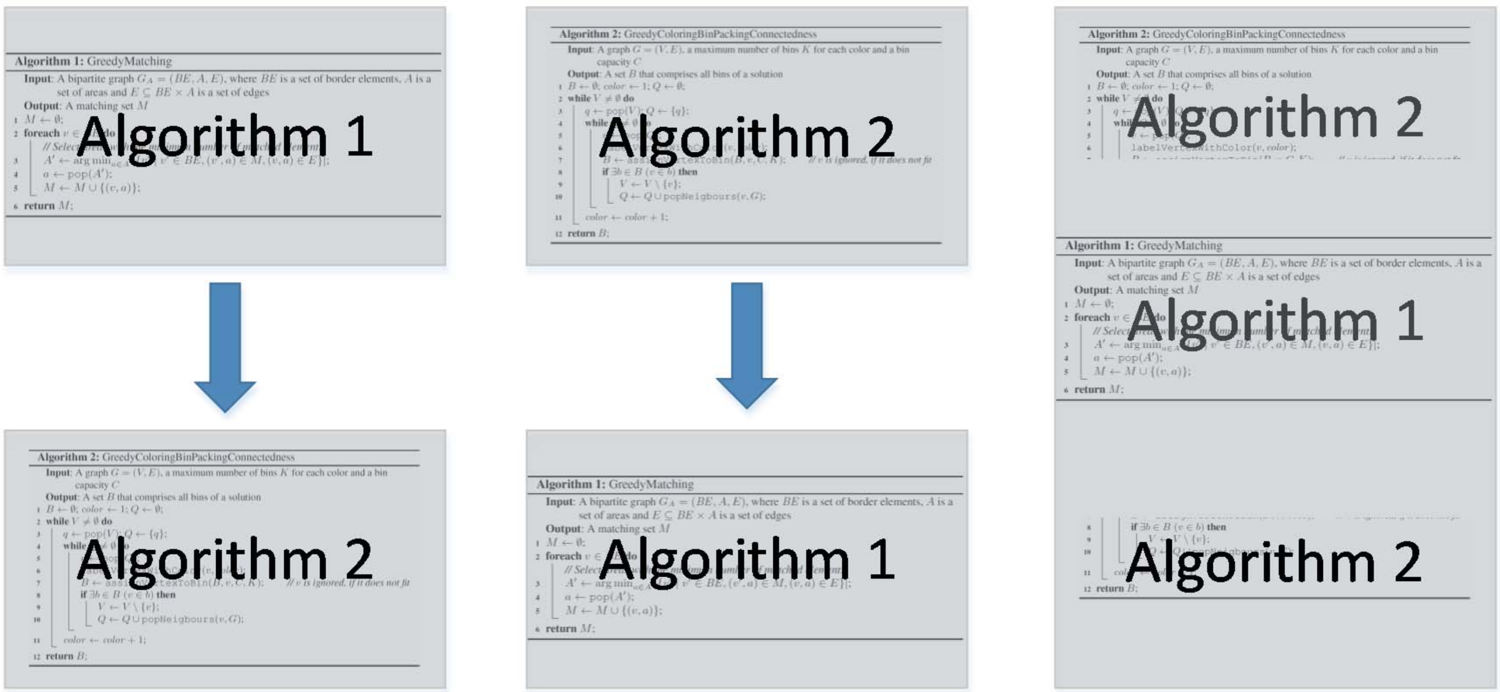
Algorithm 1: Matching (P4)

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

CCP greedy methods



Heuristics in ASP

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

- Specified using atoms `_heuristic(a,m,v,p)`
  - `a` – denotes an atom for which a heuristic value is defined
  - `m` – one of the modifiers (`init, factor, level and sign`)
  - `v` – a value
  - `p` – a priority of the definition

- Activated using `--heuristic=domain`

- Shortcuts are used, for instance:

  `_heuristic(a,true,v)` – assign `true` to an atom a at a level `v`

  Atoms with higher levels are assigned `true` first

Example

Program

```
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).
```

Grounding

```
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).
```

Solving

```
selected(c,3)
Choices: 1        (Domain: 1)
Conflicts: 0      (Analyzed: 0)
```

Greedy vs. ASP

Greedy

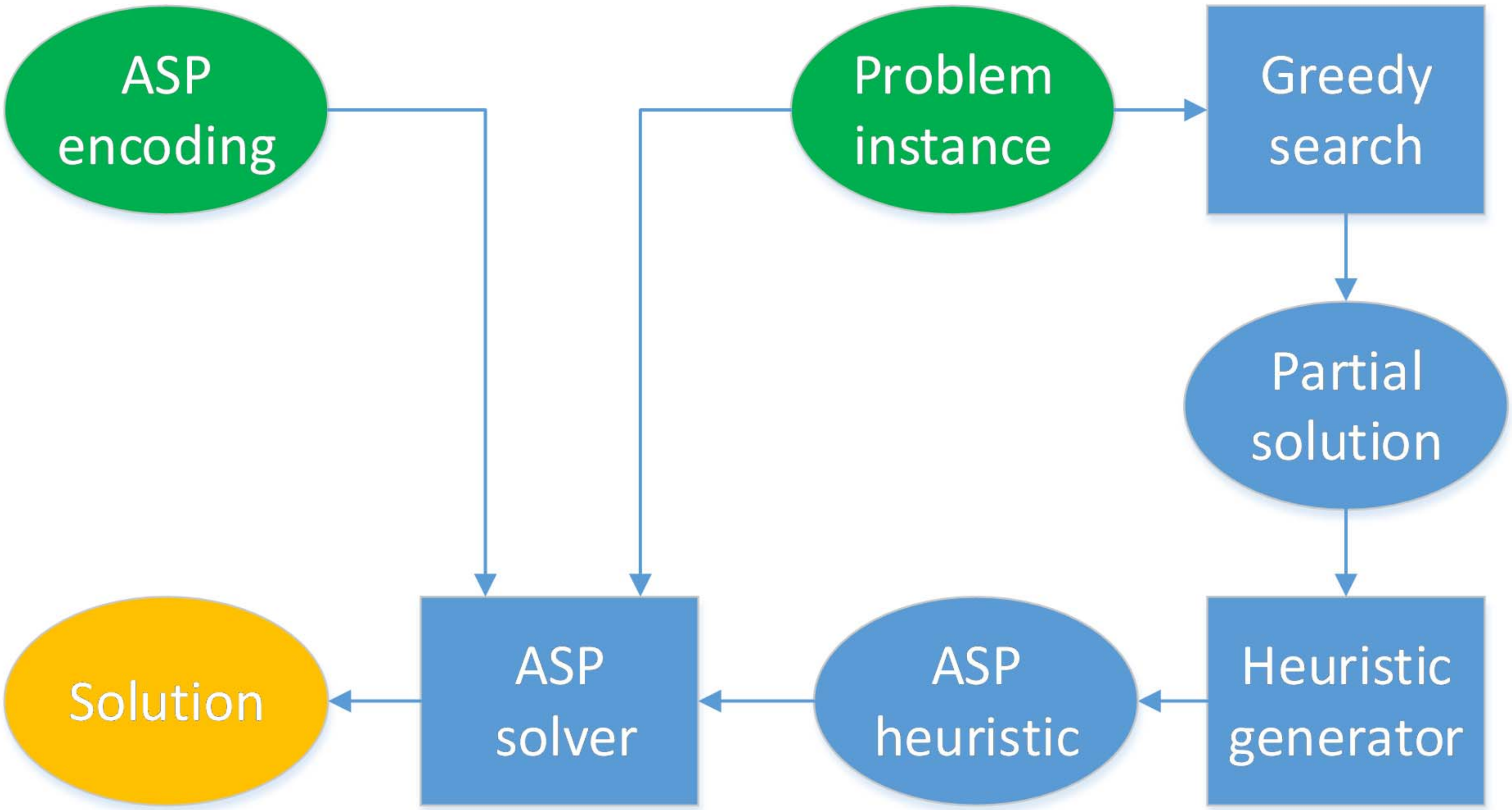
- ☺ An implementation of a subproblem of the CCP can be done easy and is usually efficient
- ☹ Designing a mixed greedy method for the problem is difficult

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))

- 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

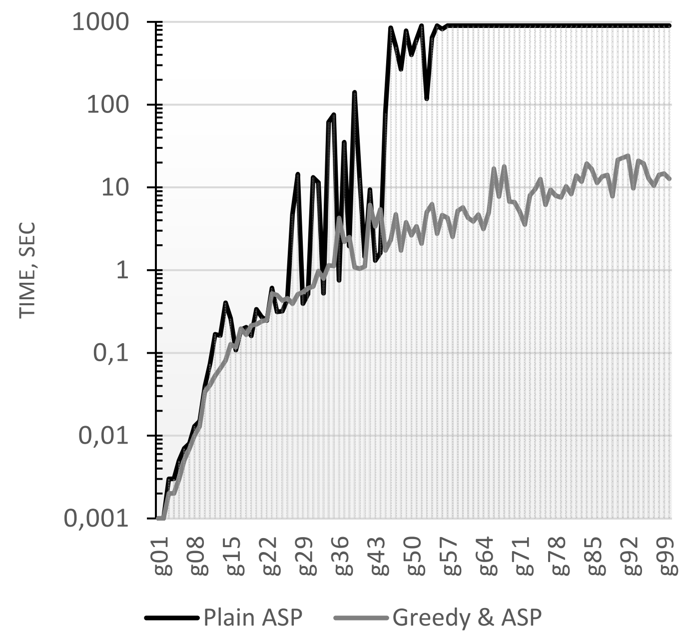
(ASP FF(D), BF(D) and NF(D) heuristics do not work!)

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

Experiment 2

- Set 2 (up to 500 vertices)
- 54/100 from 100 instances were solved using the plain/combined methods, resp.
- The quality of solutions (#bins, #colors) is the same in the instances solved by both approaches

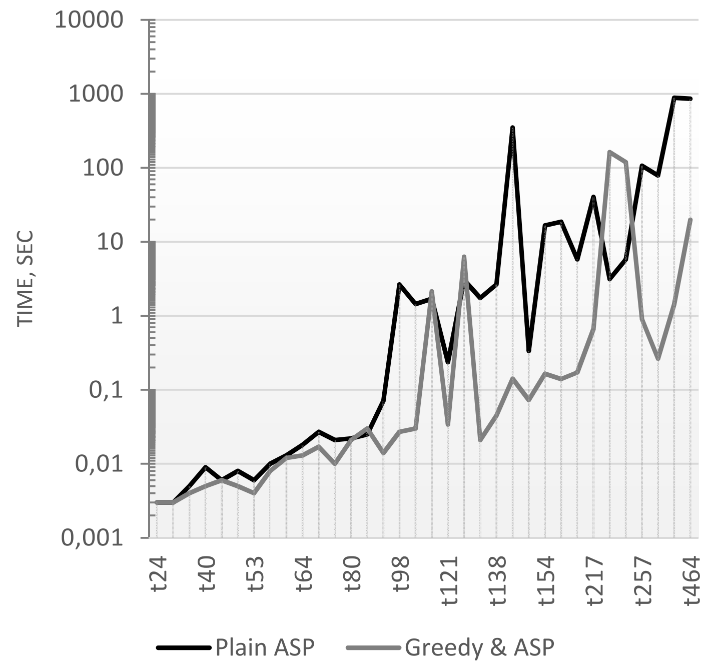
Statistics	Plain ASP	Greedy and ASP
	Solving	Solving
Median	0,521	3,474
Average	101,215	5,536
Total	5465,600	553,614
Min	0,001	0,001
Max	847,692	24,086



Experiment 3

- Set 3 (up to 1004 vertices)
- 36/38 from 48 instances were solved using plain/combined methods, resp.
- The quality of solutions (#bins, #colors) is the same in the instances solved by both approaches

Statistics	Plain ASP	Greedy and ASP
	Solving	Solving
Median	1,571	0,040
Average	69,019	13,818
Total	2484,684	525,067
Min	0,003	0,003
Max	885,477	195,809

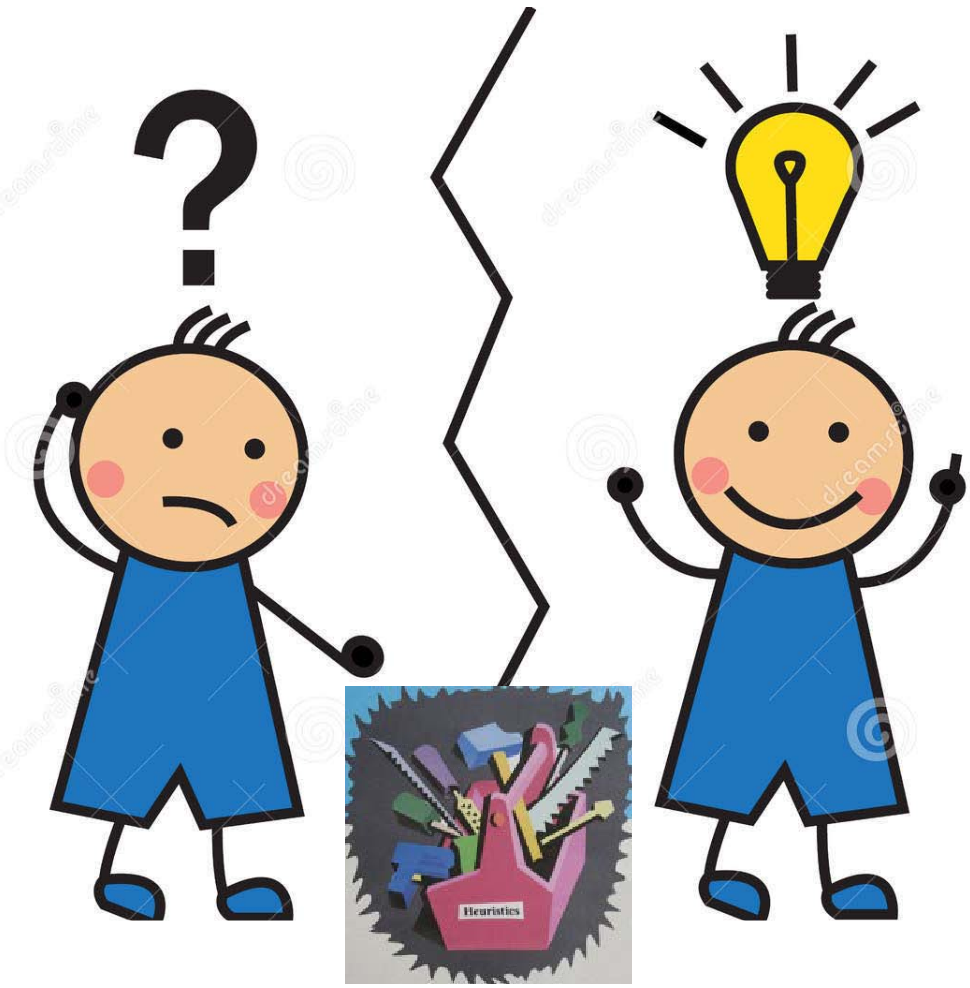


Summary

- 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 and up to 18 times faster on average

Gebser, Ryabokon and Schenner, *Combining Heuristics for Configuration Problems Using Answer Set Programming*. LPNMR 2015.

Thank you! Questions?



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