FAKULTÄT FÜR !NFORMATIK

Faculty of Informatics

dbai Database and Artificial Intelligence Group

Shift Design with Answer Set Programming

LPNMR 2015

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Relevance

Finding appropriate staff schedules is of great importance because ...

- work schedules influence health, social life, and motivation of employees at work.
- workforce requirements must be met to ensure the quality of services and operations.
- the required number of employees fluctuates throughout time periods, while operations dealing with critical tasks are often performed around the clock.
    - Examples include ...
        - emergency services
        - air traffic control
        - call centers
        - etc.

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  - Examples include ...
    - emergency services
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    - etc.
- Related Work:
  Team-Building at the Gioia-Tauro seaport [Grasso et al., 2010]

The Shift Design Problem

Input:

- A set of consecutive *time slots* of equal length (*planning horizon*)
- For each time slot, the number of required employees
- A set of *shift types* with associated parameters
    - *min-start* and *max-start*
    - *min-length* and *max-length*

shift type	*min-start*	*max-start*	*min-length*	*max-length*
M	07:00	08:00	07:00	09:00
D	10:30	11:30	07:00	09:00
A	14:00	16:00	07:00	08:00
N	22:00	24:00	07:00	09:00

Table 1: Example of possible shift types

The Shift Design Problem

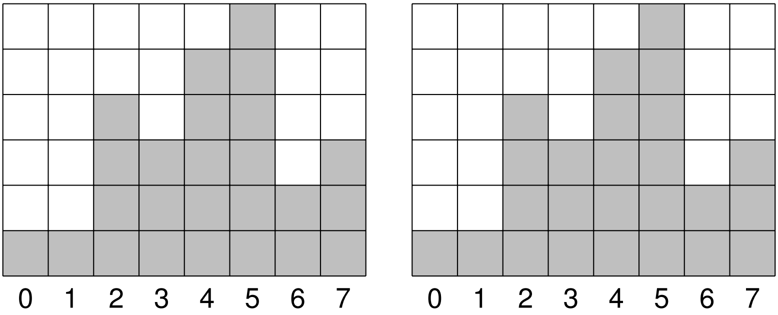
Solution:

- A set of *shifts* with associated parameters
  - The starting time *start*
  - The duration of the shift *length*
  - The number employees assigned to the respective shift
- Each of the generated shifts must belong to some shift type!

Optimization Criteria:

- Minimize the number of shifts
- Minimize understaffing
- Minimize overstaffing

A Small Example



shift type	*min-start*	*max-start*	*min-length*	*max-length*
A	2	2	2	4
B	4	5	2	4
C	6	7	2	4

Table 2: Allowed shift types

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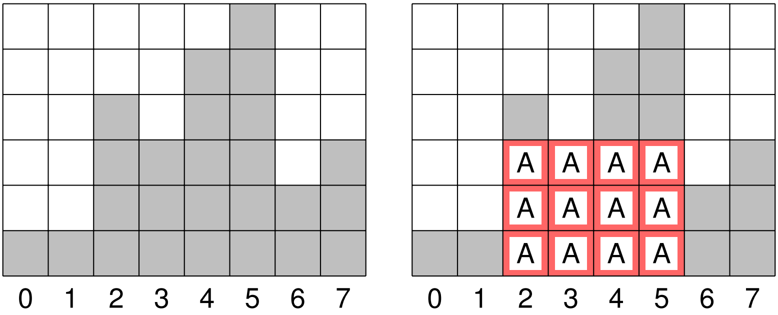

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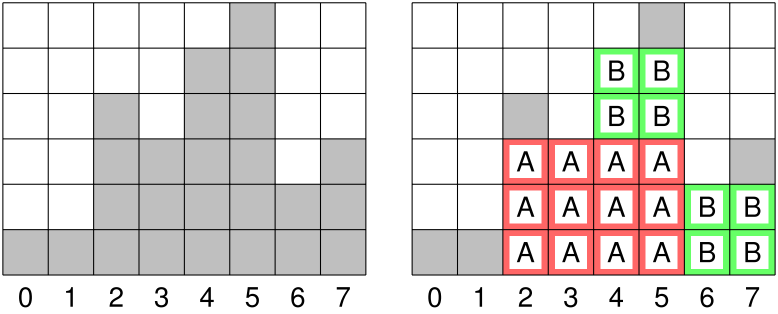

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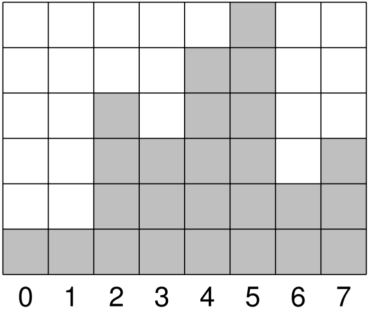

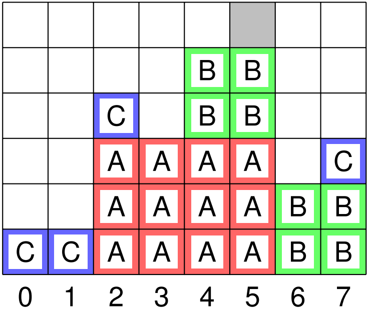

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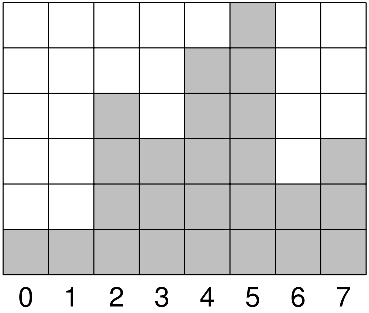

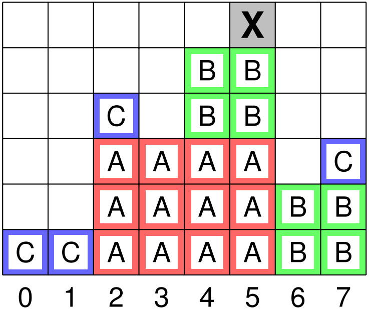

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Main Challenge

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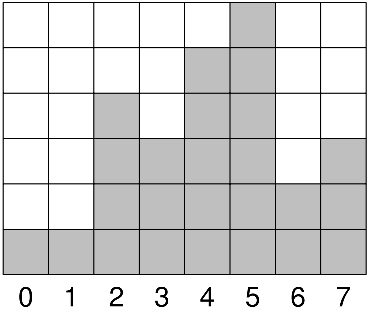
Important Ingredients of Our Encoding

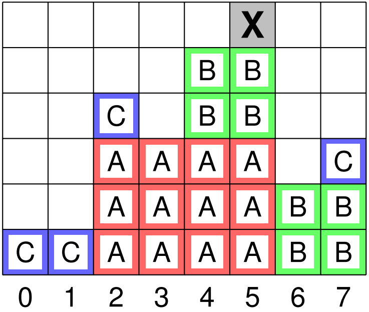
- Inverted decision strategy
  - Instead of guessing start, length and workers for a shift explicitly ...
  - Guess coverage of personnel requirements for a time slot and ...
  - Determine the shifts on this basis.
- Use closed intervals for quantitative values
  - Make implicit information explicit for the solver to speed up search.

The Small Example Revisited

Inversion of Decision Strategy

- Naive guessing of concrete values for start, length and the number of workers for each shift involves three dimensions and leads to an unnecessary complex decision strategy.





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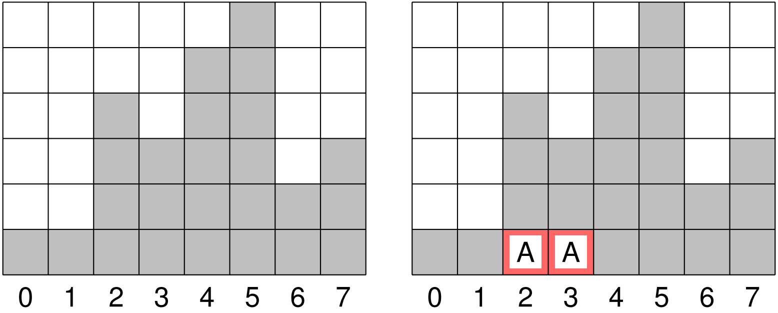

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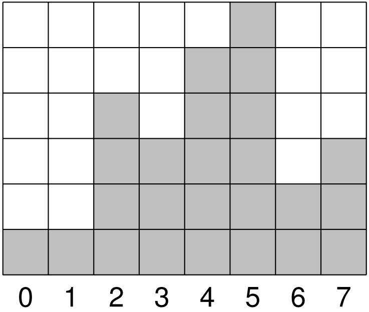

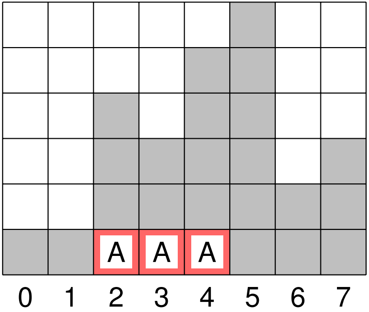

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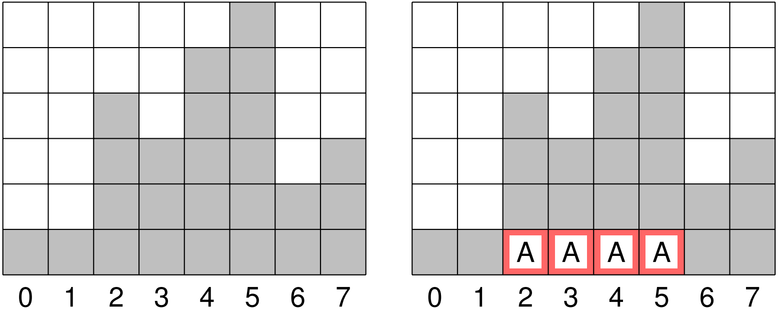

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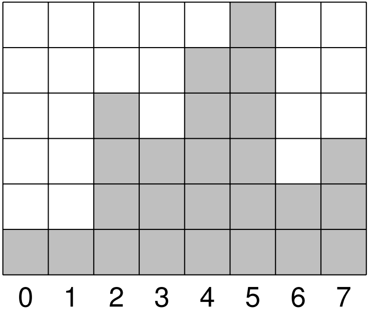

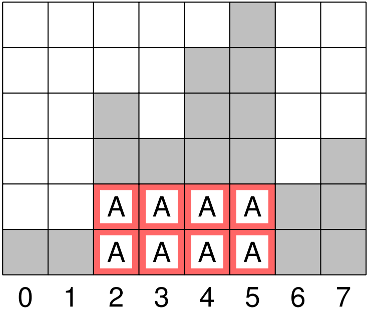

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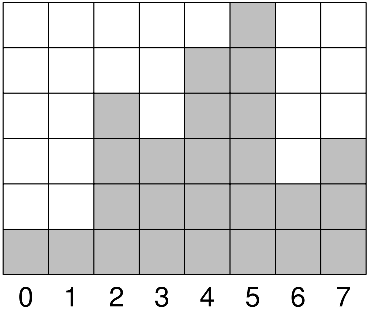

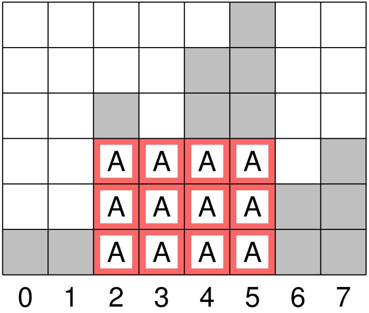

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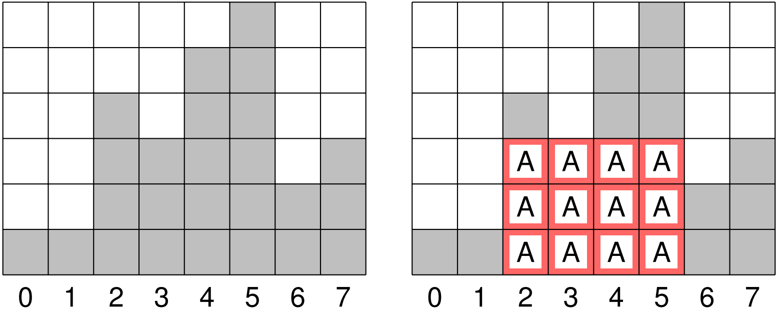
- Naive guessing of concrete values for start, length and the number of workers for each shift involves three dimensions and leads to an unnecessary complex decision strategy.
- Isn't it easier to just guess the coverage of requirements?



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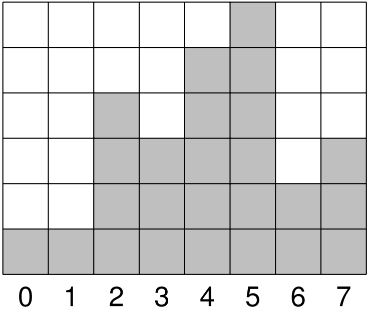

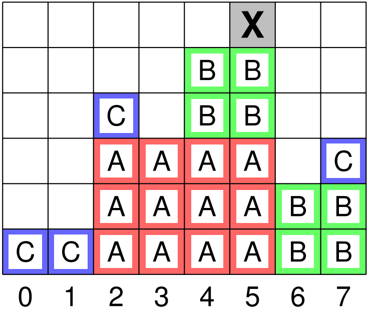

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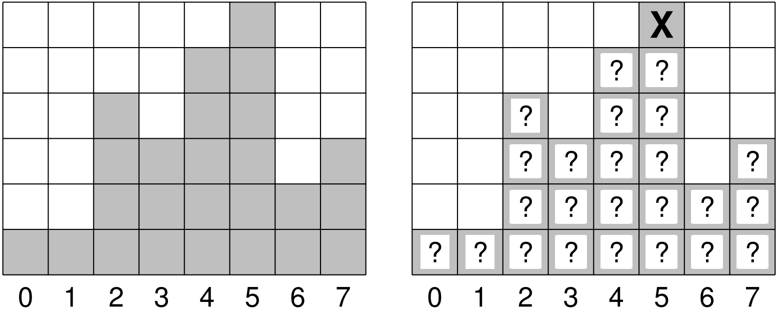

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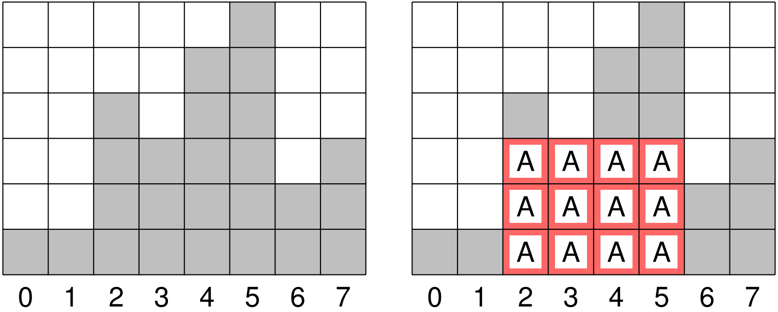

What we can see at one glance:

- One shift of type “A” is scheduled:
  - Start: 2
  - Length: 4
  - Workers: 3

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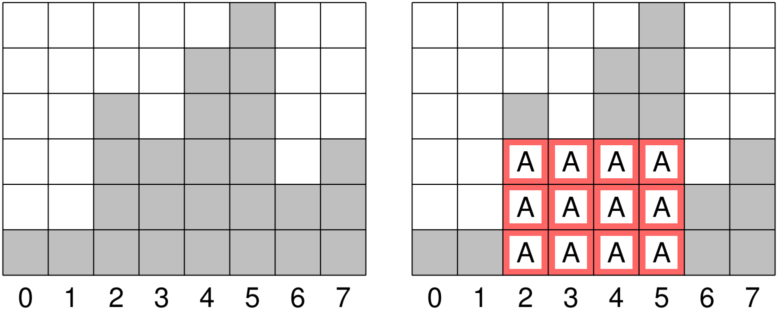
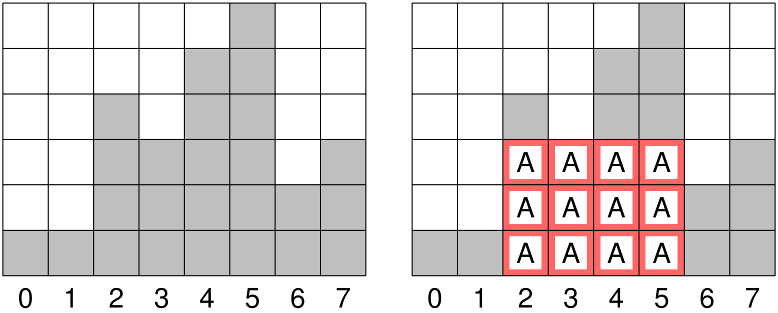


What we can see at one glance:

- One shift of type “A” is scheduled:
  - Start: 2
  - Length: 4 ... but also {3, 2, 1}
  - Workers: 3 ... but also {2, 1}

Represent Quantitative Values via Closed Intervals

- Similar Idea is used in [Crawford and Baker, 1994]
  Application of Satisfiability Algorithms to Scheduling Problems
  - “Coherence Criteria”



The Goal:

Make implicit information explicit for speeding up search!

Experiments

- Based on four datasets[1]:
  - DataSet1 (30 Instances, solvable without over- and understaffing)
    - Known optimum, small number of necessary shifts
  - DataSet2 (30 Instances, solvable without over- and understaffing)
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  - DataSet3 (30 Instances requiring over- and/or understaffing)
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  - DataSet4 (3 Instances derived from a real-world setting)
    - Unknown optimum

[1] Introduced in [Musliu, 2001, Musliu et al., 2004].
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Experiments

- Based on four datasets[1]:
  - DataSet1 (30 Instances, solvable without over- and understaffing)
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    - **Optimum found within one hour in all but two cases.**
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    - **Solutions found for 22 instances within one hour.**
  - DataSet4 (3 Instances derived from a real-world setting)
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Conclusion and Future Work

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In fact, we showed that using our proposed approach we are able to provide global optima for four hard instances, not previously solved to the optimum.

- Future Work:
  - Exploit Clingo's integrated features, i.e., use its domain heuristics.
  - Combine ASP with meta-heuristics or min-cost max-flow techniques.
  - As our presented results open up the area of workforce scheduling for ASP, investigate related problems.

Acknowledgments

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