Solving Practical Configuration Problems Using UML

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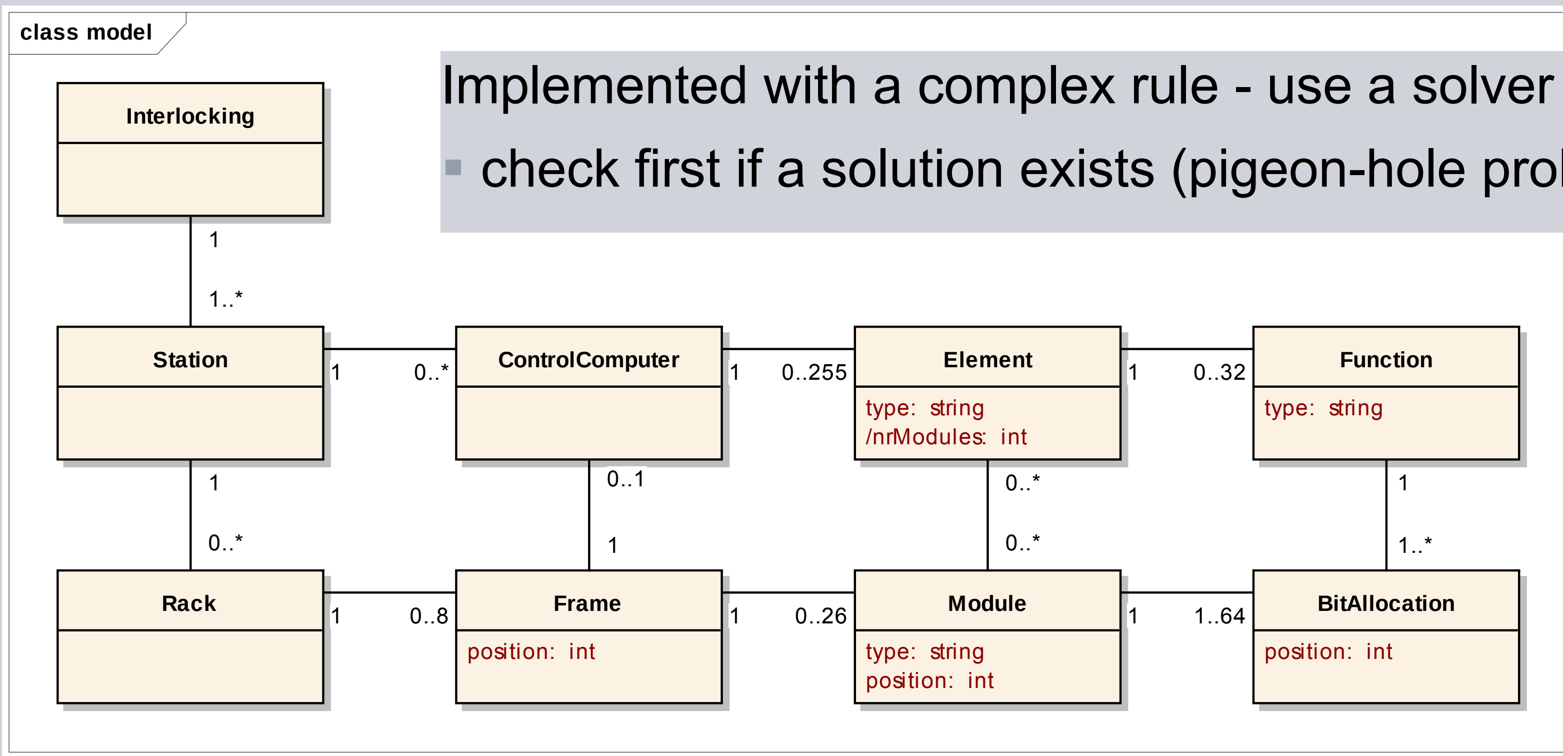
The initial problem

Hardware configuration for railway interlocking system

- given the elements and their functions, how much hardware is needed?
- actually create and configure hardware later (sizing problem)



Implemented with a complex rule - use a solver instead?

- check first if a solution exists (pigeon-hole problem)

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Academic approach

Subset of the problem:

- UML classes and minimal number of instances
- associations with lower/upper bounds for cardinalities (multiplicities)

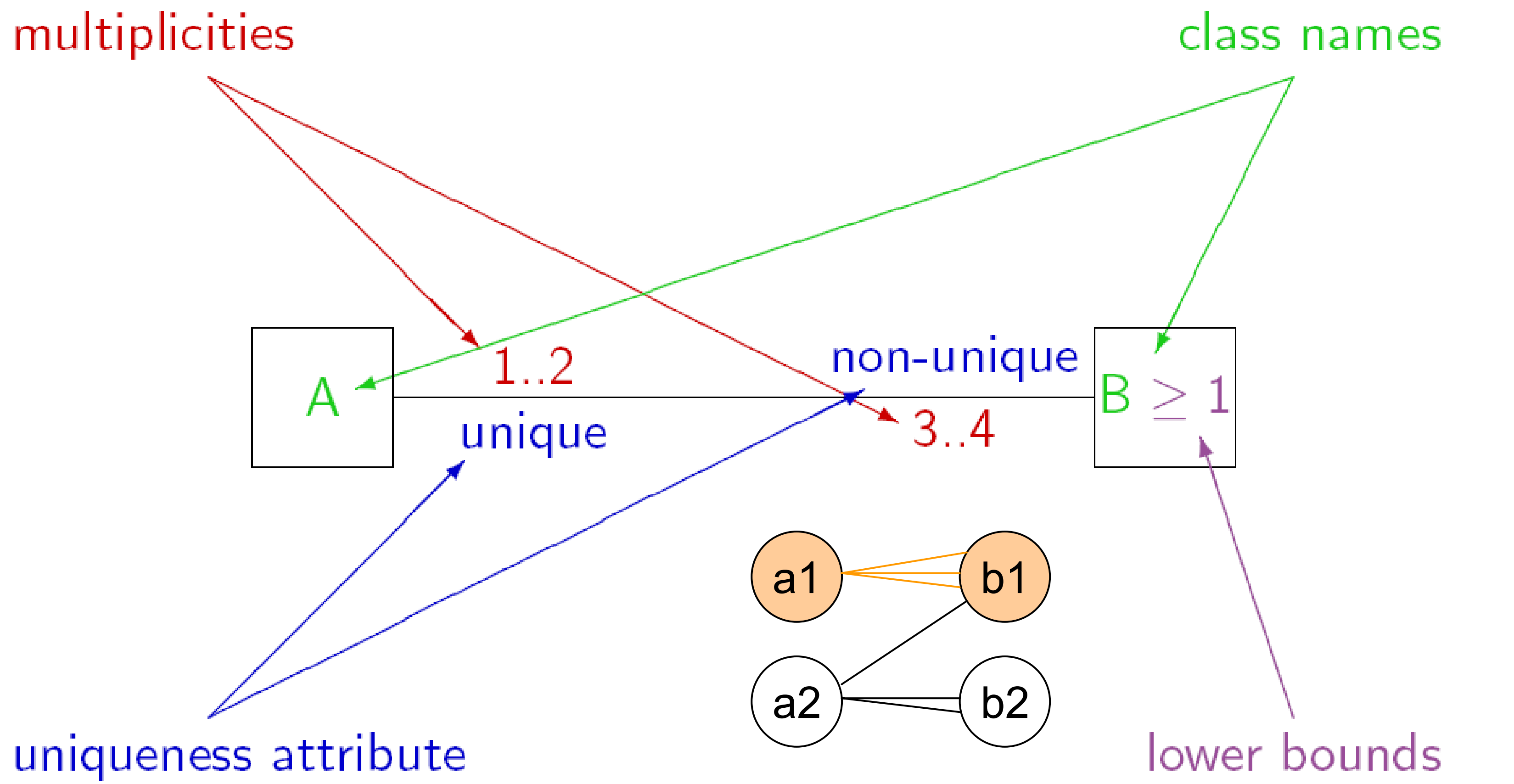
Salzer/Feinerer: paper at TASE 2007

- transform problem into linear Diophantine inequalities
- only 2 variables in inequalities: still NP-complete
- no upper bound of sum: polynomial
- algorithm with weighted directed graphs: O (inequalities * variables^2)
- existence of a solution, minimal solution: correspond to diagram

Dissertation of Feinerer:

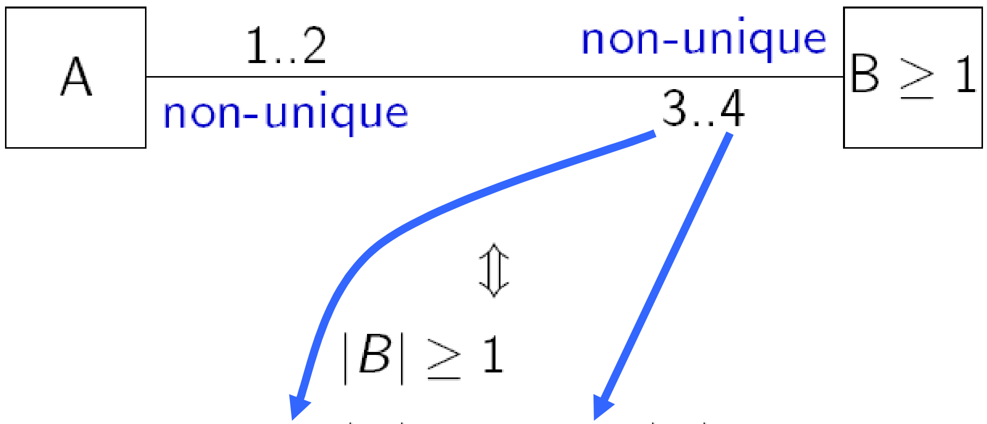
- won Austrian INiTS Award 2007 for innovative business ideas

Specification with UML



unique = "count objects" (default) non-unique = "count links"

Transformation to linear inequalities



$$\Updownarrow$$

$$|B| \geq 1$$

$$3 \cdot |A| \leq n \leq 4 \cdot |A|$$

$$1 \cdot |B| \leq n \leq 2 \cdot |B|$$

$$(n \ \dots \ \text{number of links})$$

$$\Updownarrow$$

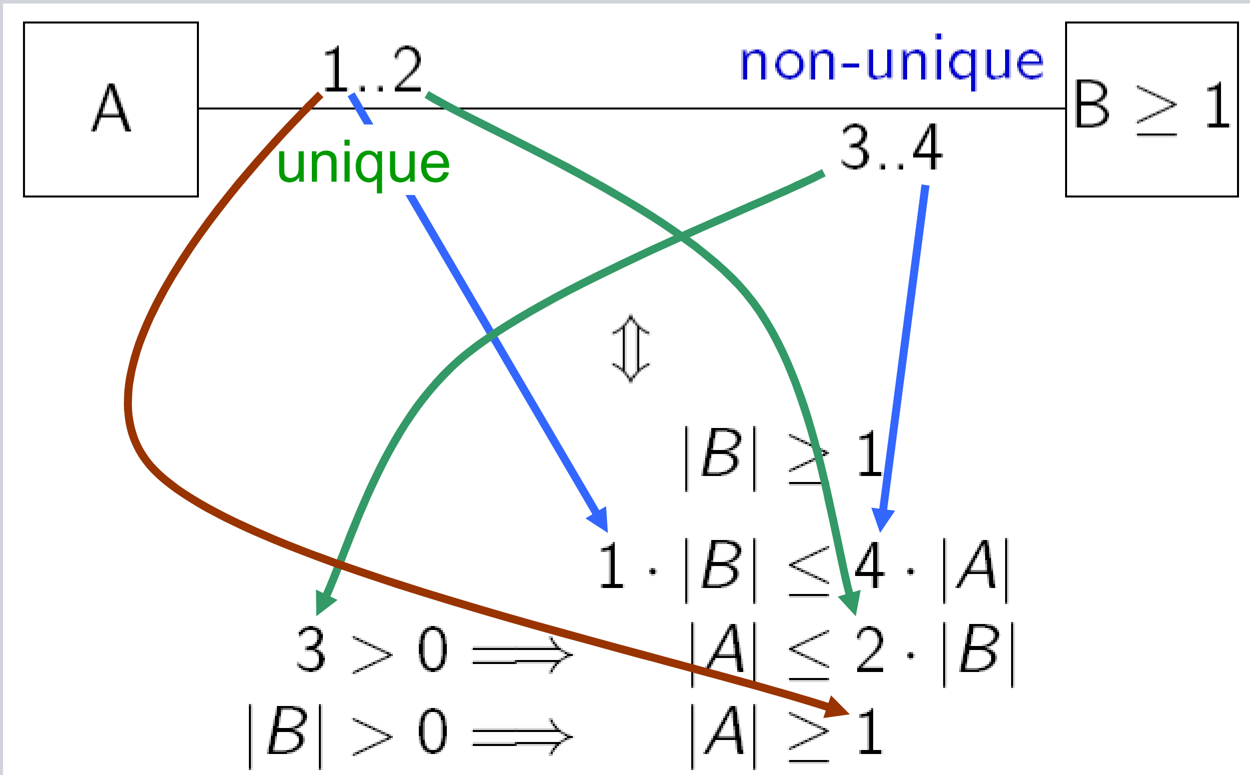
$$|B| \geq 1$$

$$1 \cdot |B| \leq 4 \cdot |A|$$

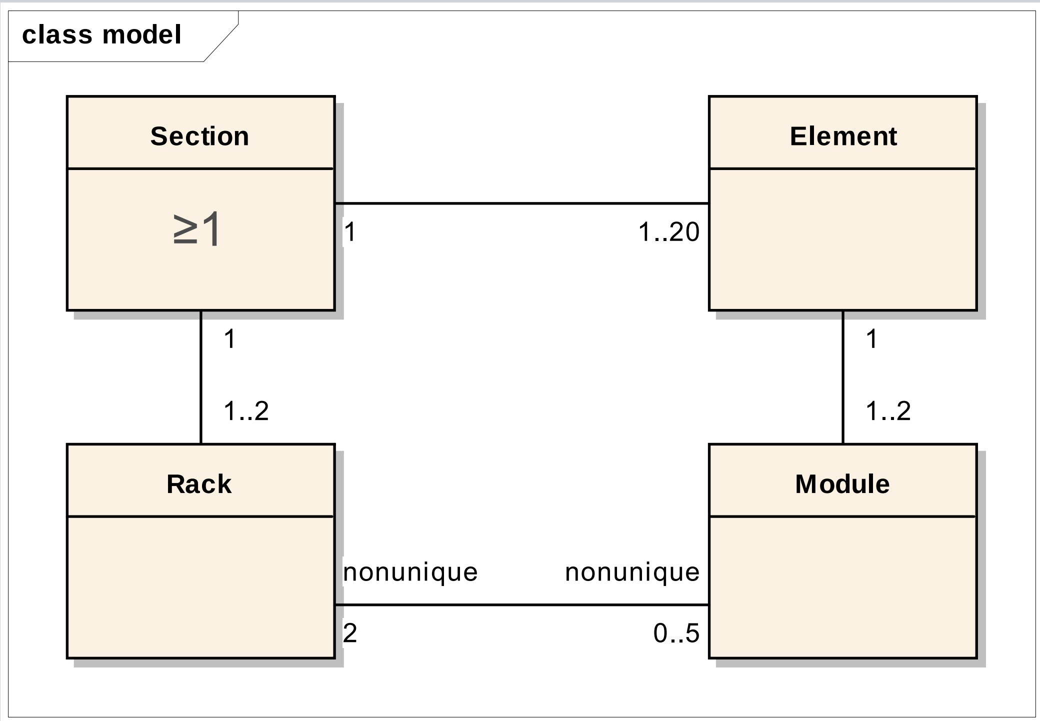
$$3 \cdot |A| \leq 2 \cdot |B|$$

- lower and upper bounds for the number of links (i.e. size of the relation)
- similar considerations for unique and mixed cases
- inequalities are complete and correct (solutions of inequalities correspond to valid object diagrams)

Theoretic example



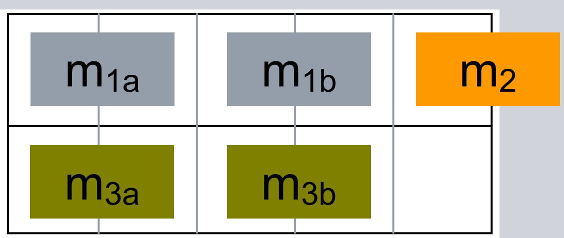
Practical example



given 3 elements

- e1 with 2 modules
- e2 with 1 module
- e3 with 2 modules

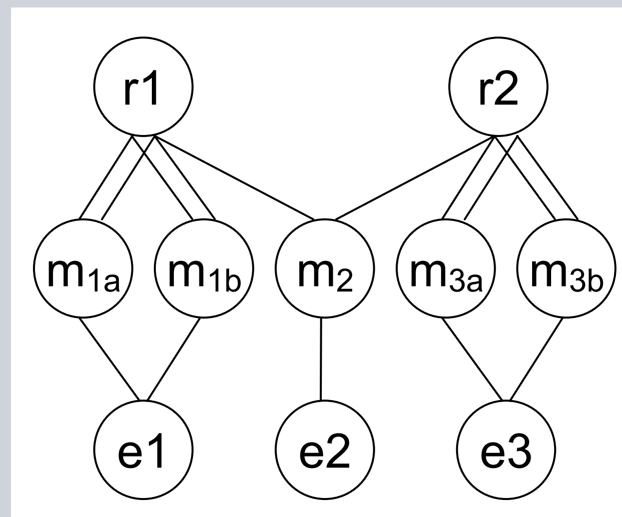
needs 2 racks ???



$2\ |Module| \leq 5\ |Rack|$

$|Module| = 5$

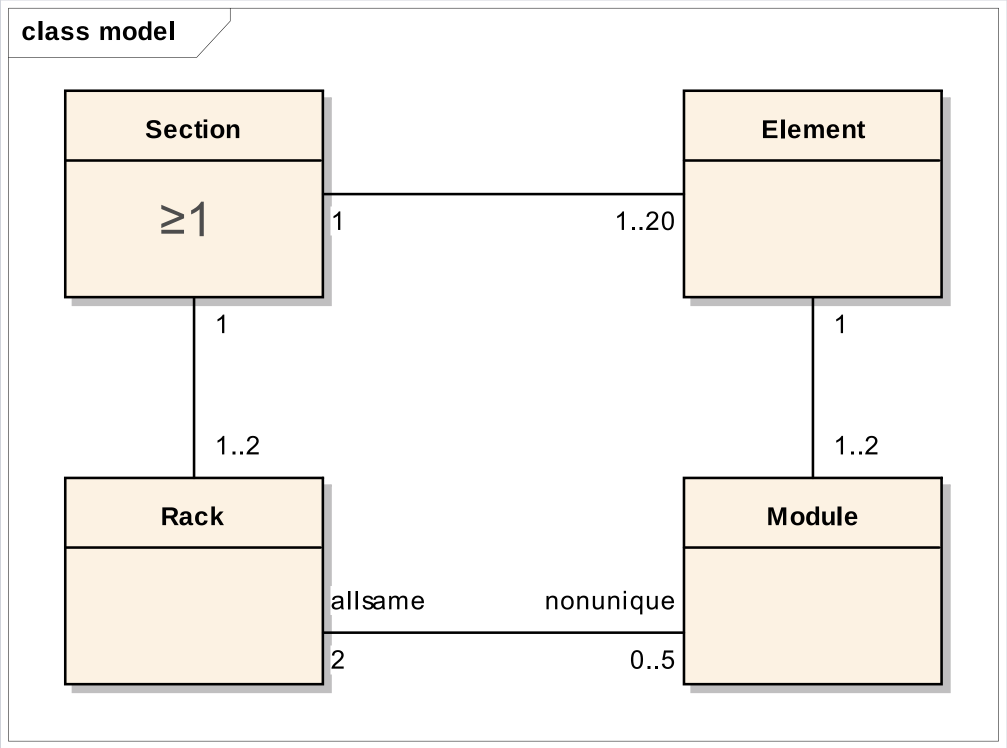
$\rightarrow\ 2 \leq |Rack|$



Equality constraints

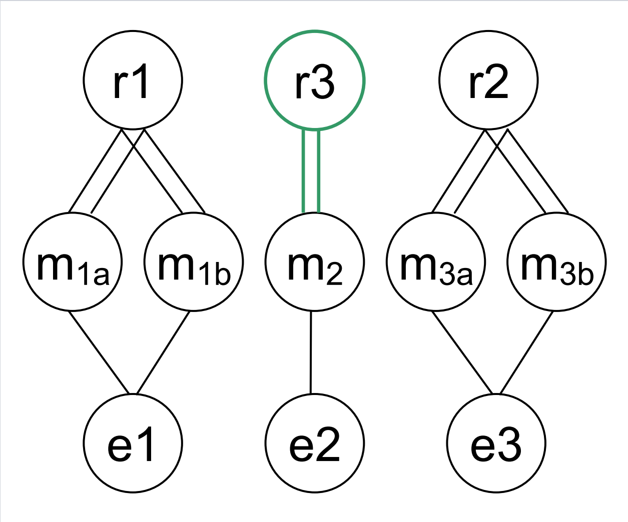
Additional constraints other than for multiplicities

- e.g. "all slots occupied by a module must belong to the same rack"



Extend UML diagram

- introduce tag "all-same"



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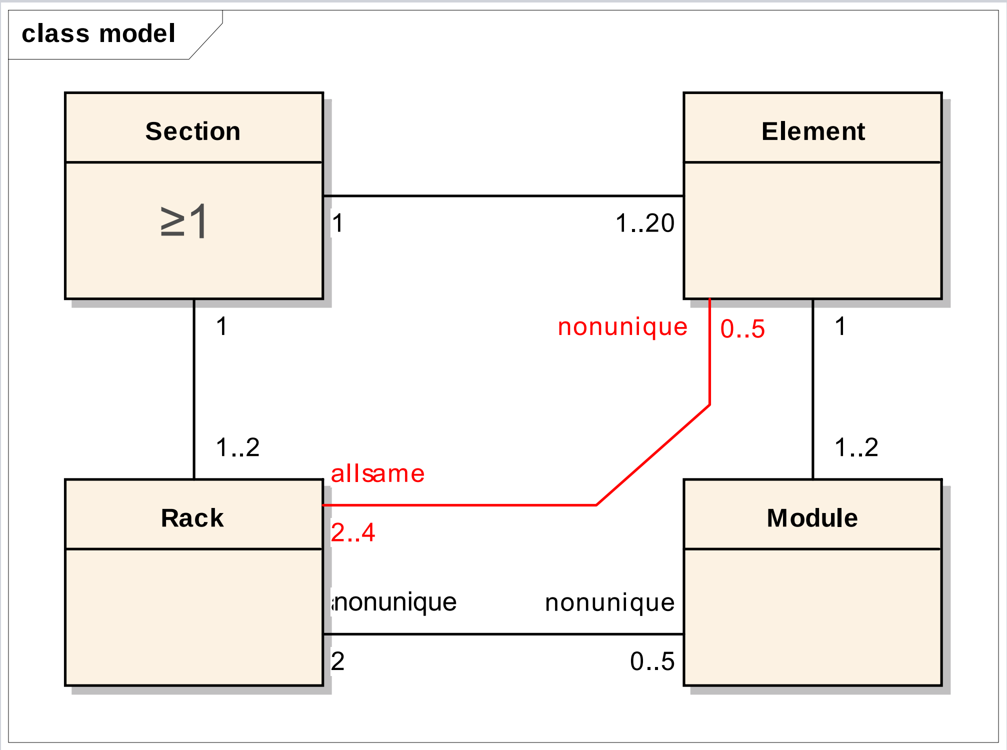
Equality constraints (2)

Additional constraints other than for multiplicities

- e.g. "all slots occupied by a module must belong to the same rack"



Extend UML diagram

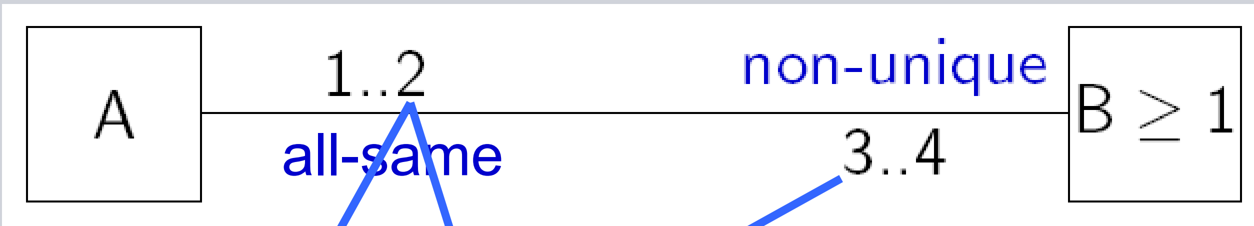
- introduce tag "all-same"

Inequalities:

- $|Module| \leq 2 \cdot |Rack|$
- (max. 5/2 = 2 modules fit in a rack)
- links = $2 \cdot |Module|$
- (each module requires exactly 2 links to a rack)

- e.g. "all modules of an element must be placed in the same rack"

Additional inequalities



Inequalities:

$2 > 0 \rightarrow \lceil 3/2 \rceil \cdot |A| \leq |B|$
$1 > 0 \rightarrow |A| \leq \lfloor 4/1 \rfloor \cdot |B|$

simplify to:

$2 \cdot |A| \leq |B| \leq 4 \cdot |A|$

Interpretation:

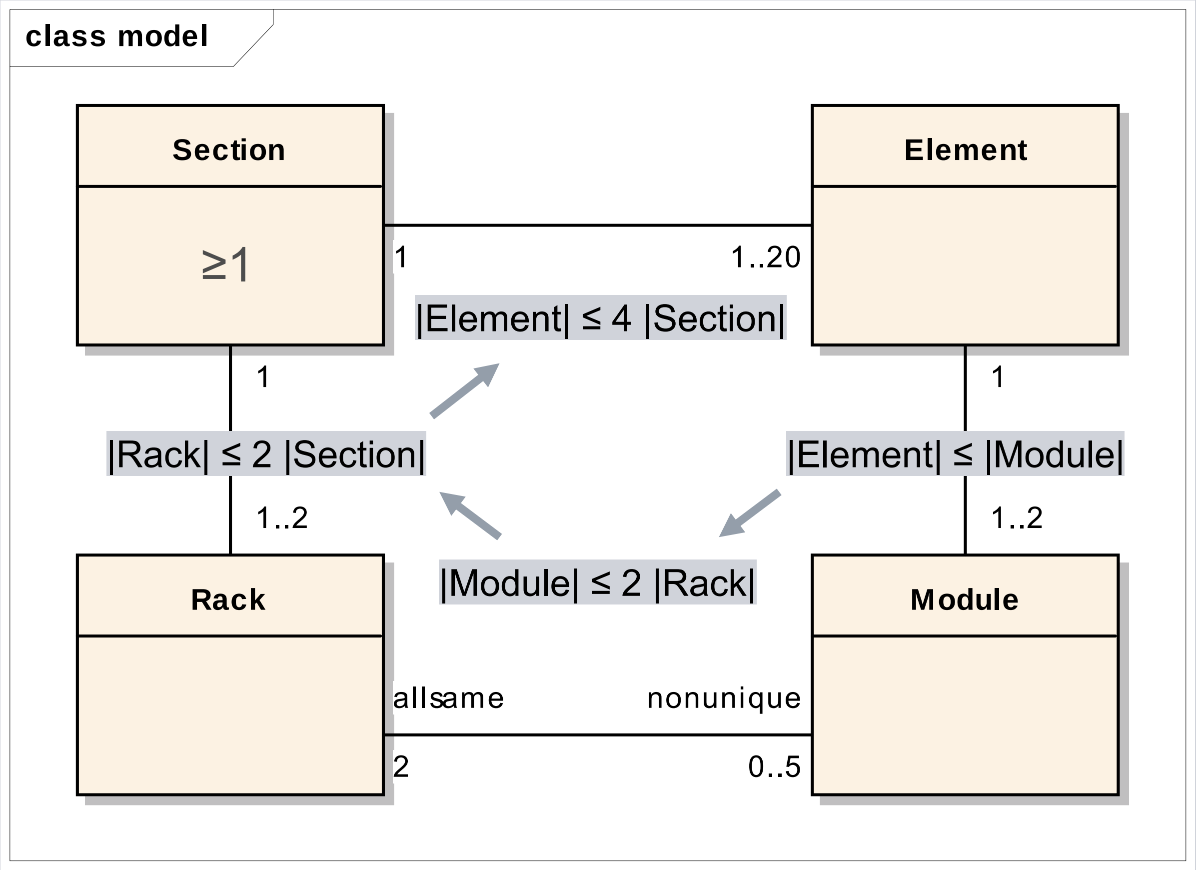
- "Slots" to be filled: 3..4
- Size in slots: 1..2
- 2 B (size 1 and 2) in an A
- up to 4 B of size 1

- Similar inequalities for other combinations (all-same/unique, etc.)
- Those additional inequalities do not corrupt the existing approach (computational properties, finding and mapping of solutions)

Reasoning about cardinalities

By-product of checking the consistency of inequalities:

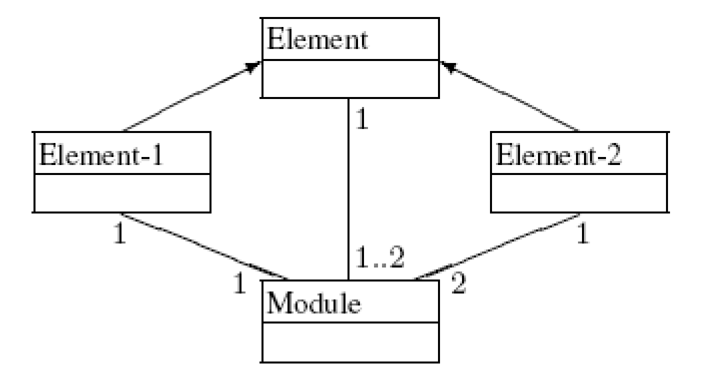
- Find stronger relationships (restricted cardinalities)
- for Section to Element: 1..4
- instead of 1..20



Type-specific cardinalities

Different multiplicities depending on the type of an element

Idea: use sub-classes



Additional equation:

$$1 \cdot |Element\text{-}1| + 2 \cdot |Element\text{-}2| = 1 \cdot |Module|$$

Open issue:

- extend existing algorithm
- computational complexity?

Remaining issues

Use the approach for the completion of partial configurations

- e.g. "how many more elements will fit into a section?"
- up to now: static analysis, finding (minimal) solutions from scratch

Make use of derived associations

- composed by a path over several classes, e.g. Element - Module - Rack
- used for coping with additional non-numeric constraints like "an element and the rack for it must belong to the same section"

Extend the approach for handling more types of constraints

- e.g. for numerical attributes or with additional diagram extensions
- if some constraints cannot be incorporated: generate-and-test solutions

Integration into configurators used in practice

- usability, performance
- up to now: academic prototypes

Contact

Thank you for your attention!

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