Modelling and Solving Configuration Problems on Business Processes Using a Multi-Level Constraint Satisfaction Approach

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1. Introduction

- Management of dependencies between business processes:
  - Problem: inconsistent process modellings.
  - Inconsistencies should be discovered in an early stage of modelling.
    - Reduce amount of time and cost.
  - Requirements of business processes depends on complex relations between the processes.
  - Usually the results of a foregoing process are needed by a subsequent one.

- Dependencies are relations between arbitrary attributes of business processes, examples are:
  - sequential dependencies
  - hierarchical dependencies

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2. Consistent Configurations through Constraint Satisfaction

- Consistent configurations of business processes with methods out of the field of *artificial intelligence* (AI).
  - *Knowledge-based configuration*: using *constraint satisfaction* to model complex relations between (attributes of) components.

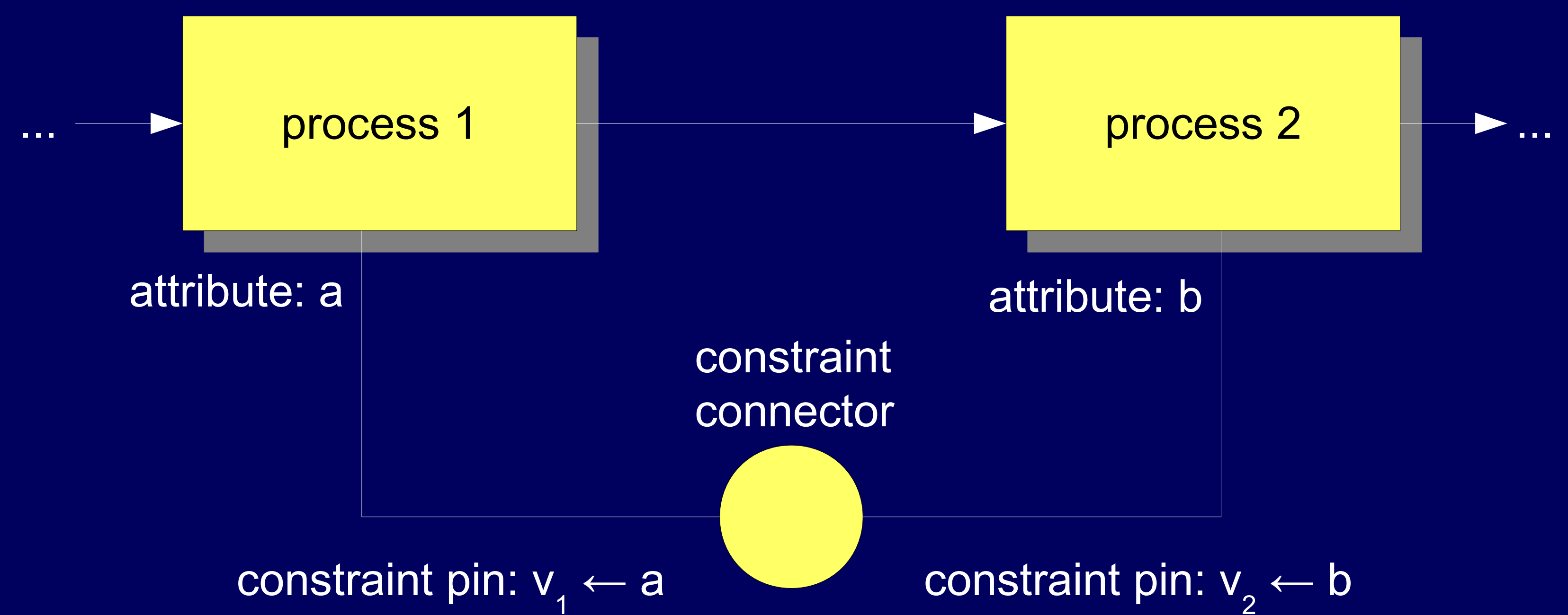
- *Constraints* as relations between attributes of processes:
  - algebraic constraints: intensional relations → equations/inequations
  - to reduce the possible assignments to variables (problem reduction)
  - for the (early) detection of inconsistencies
  - to generate solutions for a certain problem

- *Constraint Satisfaction:*
  - Characteristic: Propagation of changes throughout a “constraint net”.
  - Techniques for the handling of combinatorial and numerical problems.

3. Examples

Example: *sequential dependency*

- A constraint has to be satisfied in order that a process is allowed to be the successor of a foregoing process.

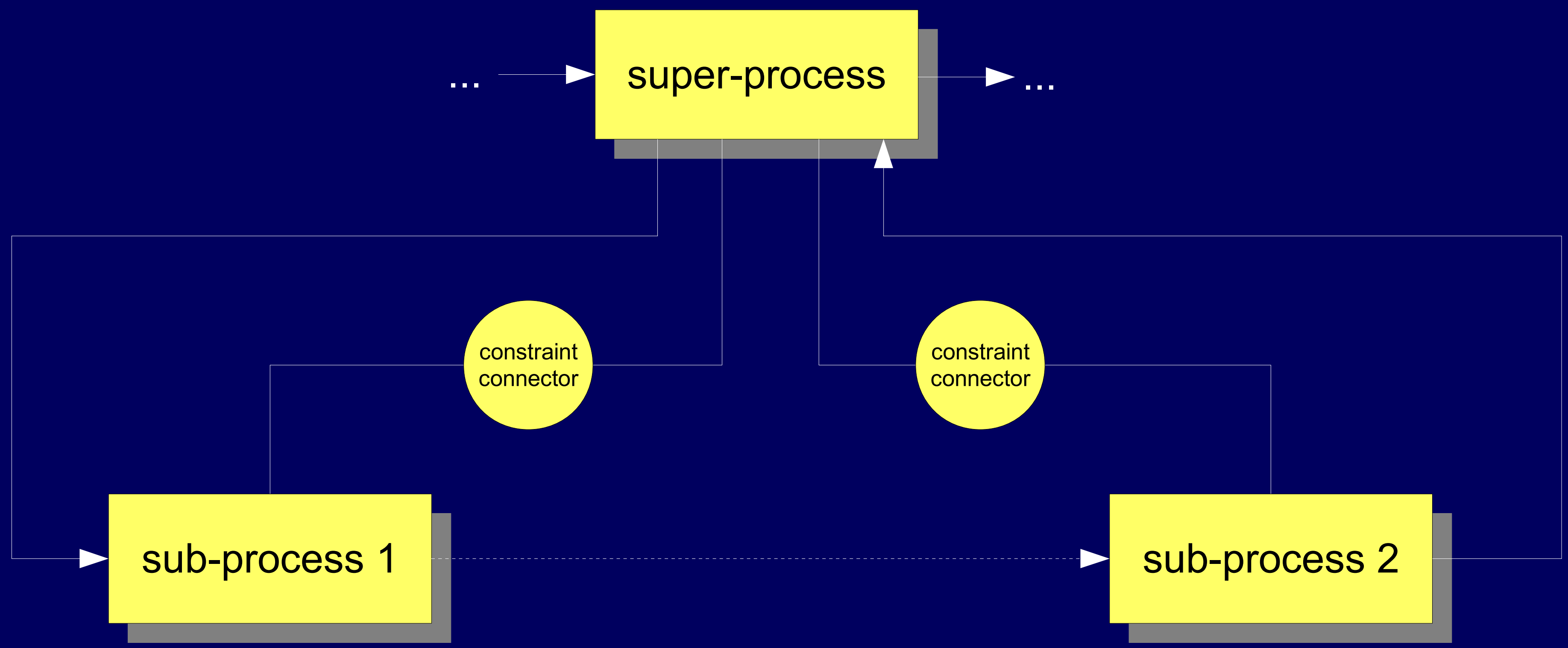


constraint relation(s): $0 < v_1 + v_2 < 10$

3. Examples

Example: *hierarchical dependency*

- A constraint has to be defined to specify processes to be allowed to be nested sub-items of upper processes, in order to satisfy all requirements of super- and sub-processes.



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4. Multi-Level Constraint Problem

- Goal: Handle different levels of nested business processes.
- Flexibility: Different layers of processes in hierarchies define different sub-problems.
  - the need to define different solutions strategies,
  - application of problem specific solving algorithms.
- For each sub-problem another solution strategy can be applied depending on:
  - the value domain of the involved variables,
  - the problem structure defined by the constraint net.
- Integration of local solutions of sub-processes has to be done on the higher-ordered level leading to global solutions and hence globally consistent configurations.

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5. Summary

- Management of dependencies between business processes.
- Avoiding inconsistencies in business process modelling using constraint satisfaction.
- Constraints can be used to define arbitrary relations between attributes of business processes, e.g.
  - sequential and
  - hierarchical dependencies.
- Nested sub-problems on different abstraction levels:
  - can be seen as multi-level constraint problem,
  - results have to be integrated to upper levels for global solutions.

Thank you for your attention!

Outline of the talk:

1. Introduction
2. Consistent Configurations through Constraint Satisfaction
3. Examples
4. Multi-Level Constraint Problem
5. Summary

Sequential and Hierarchical Dependencies

... more precisely

- sequential dependencies:
  - Relations between processes in a sequential order.
  - Relations between the input/output values: the output of a foregoing process is needed as input of a subsequent process.
- hierarchical dependencies:
  - One or more processes can be sub-item(s) of a higher-ordered process.
  - Relations between lower and higher-ordered processes.
  - Relations between the input/output values of the first/last sub-process and the input/output of the higher-ordered process.

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Constraints, Constraint Satisfaction Problem

- *Constraints* as relations between attributes of processes:
  - algebraic constraints: intensional relations → equations/inequations
  - to reduce the possible assignments to variables (problem reduction)
  - for the (early) detection of inconsistencies

- *Constraint Satisfaction Problem* (CSP):
  - Characteristic: Propagation of changes throughout a “constraint net”.
  - Techniques for the handling of combinatorial and numerical problems.
  - In the focus of intensive research and experiences for decades.
  - Efficient algorithms and heuristics:
    - reduction of the problem size/solution space
    - efficient generation of solutions
    - guarantee that specific relations hold

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Constraint Satisfaction Problem

A **Constraint Satisfaction Problem** (CSP) is a triple *CSP(V,D,C):*

$V = \{v_1, \ldots, v_n\}$ *a finite set of* ***variables***

$D = \{D_1, \ldots, D_n\}$ *associated value* ***domains*** $\{v_1 : D_1, \ldots, v_n : D_n\}$

C *a finite set of* ***constraints*** $c_i(V_i)$, $i \in \{1, \ldots, m\}$,

$c_i(V_i)$ *to set the subset* $V_i = \{v_{i_1}, \ldots, v_{i_k}\} \subseteq V$ *in relation,*

solution space for $c_i(V_i)$: $\{D_{i_1} \times \ldots \times D_{i_k}\}$

Example:

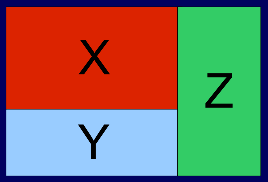
- Variables: *a* and *b* each with the value domain {0,1,2,3,4,5,6,7,8,9}
- Constraints: $a + b = 10$ and $a - b = 2$
- Solution: $a = 6$ and $b = 4$
- Note: Besides arithmetic domains also symbolic domains are feasible.

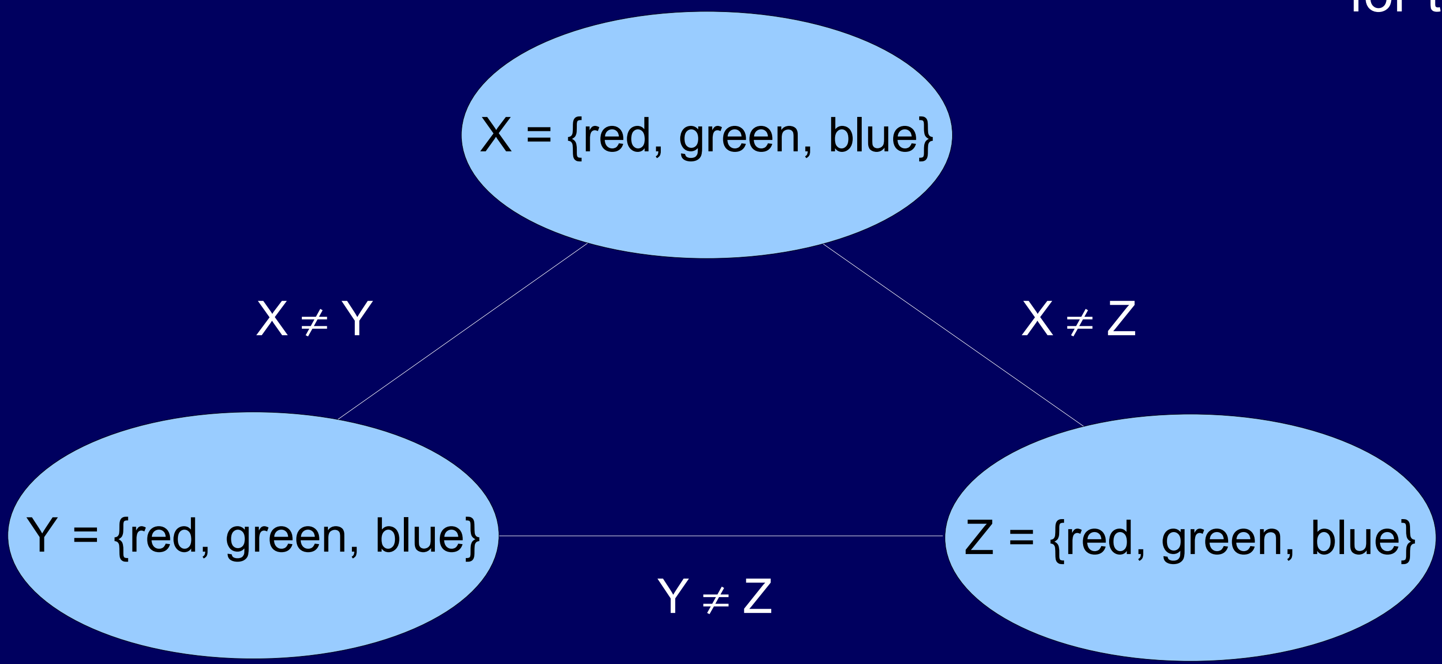
Constraint Example

Example of a constraint graph: *map coloring problem*

nodes → constraint variables
edges → constraints

A possible solution for this CSP:





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Static and Dynamic Usage of Constraints

- Usage of constraint relations for business processes:
  - static use → during modelling
  - dynamic use → during execution
- Static use during modelling:
  - constraints connect input/output variables or attributes of processes
  - test for solutions and/or inconsistencies of the static model
    - Example: $a > b$; $a = [0..4]$, $b = [5..9]$ → inconsistent model
- Dynamic use during execution:
  - test for solutions and/or inconsistencies during the execution of the business processes
  - user input or calculation results lead to reduced solution space
    - Example: $a \geq b$; $a = [0..9]$, $b = [0..9]$ → user input: $b = 5$ → $a = [5..9]$, $b = [5]$