EFFICIENT ALGORITHMS FOR FINDING DIFFERENCES BETWEEN PROCESS MODELS

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Process mining

The number of information systems around us is constantly growing…

We don't always know how they are used:

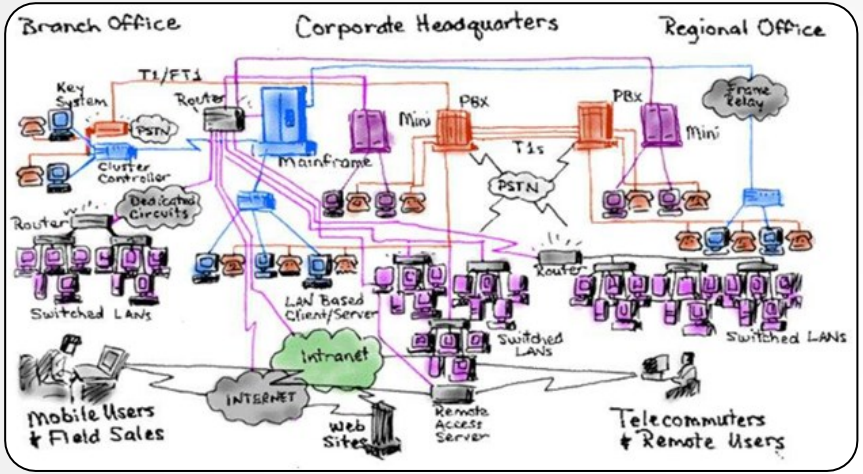
- What actions are most often performed?
- In what order?
- Are there bottlenecks?
- How far we are from the expected behavior of the system.

Process mining

User interaction:

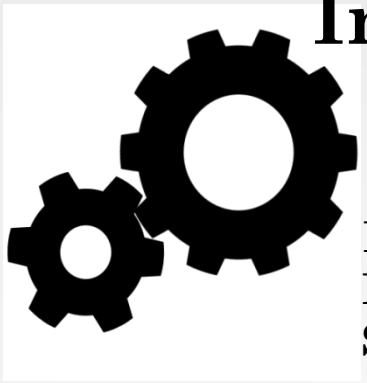
- Internet marketing;
- E-government services;

Complex multi-component systems (software process mining)



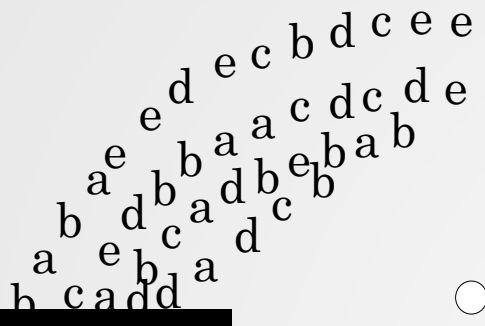
Process mining

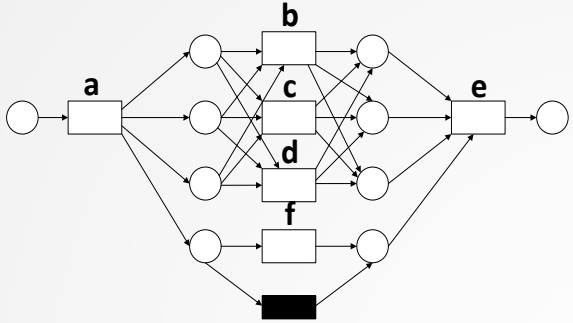
- Discovery



Industry

Process-Aware Information Systems

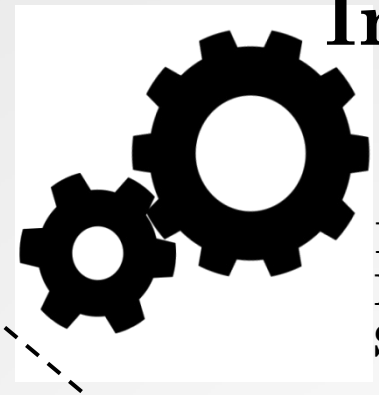




Discovery

Process mining

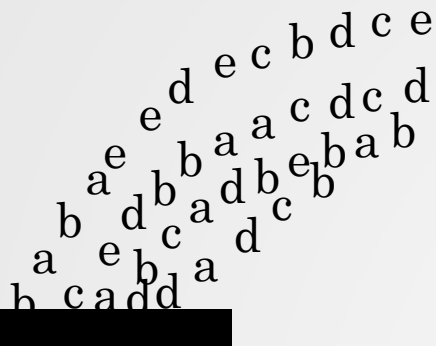
- Enhancement

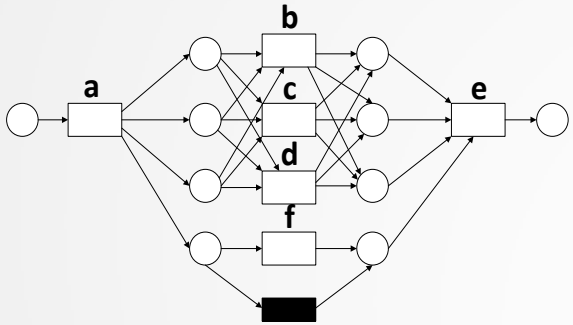


Industry

Process-Aware Information Systems

Enhancement





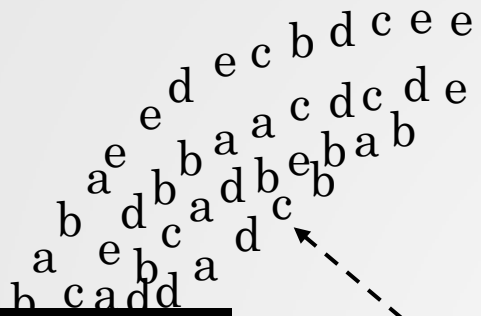
Process mining

- Conformance checking

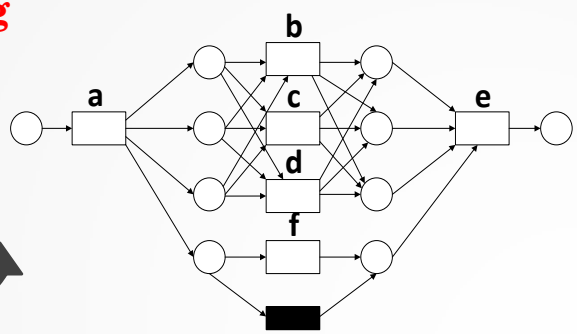
Industry

Process-Aware Information Systems

Enhancement



Conformance checking



Discovery

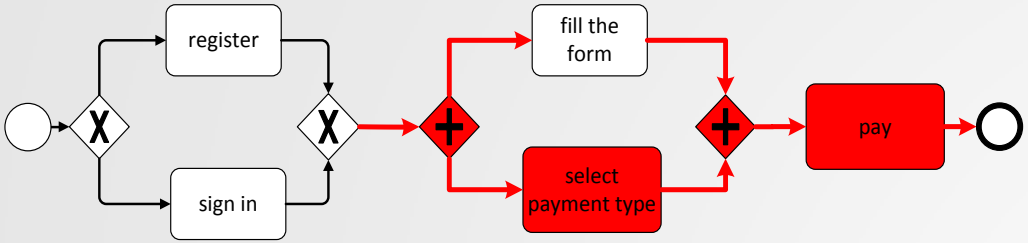
Process mining. Conformance checking

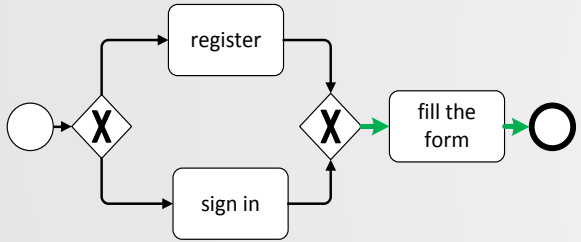
L2L – Comparison of event structures

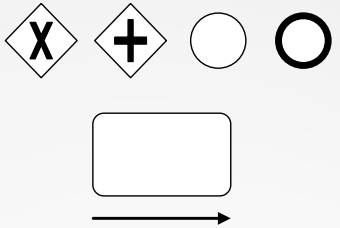
L2M – Replay techniques

M2M - Must be something visual?

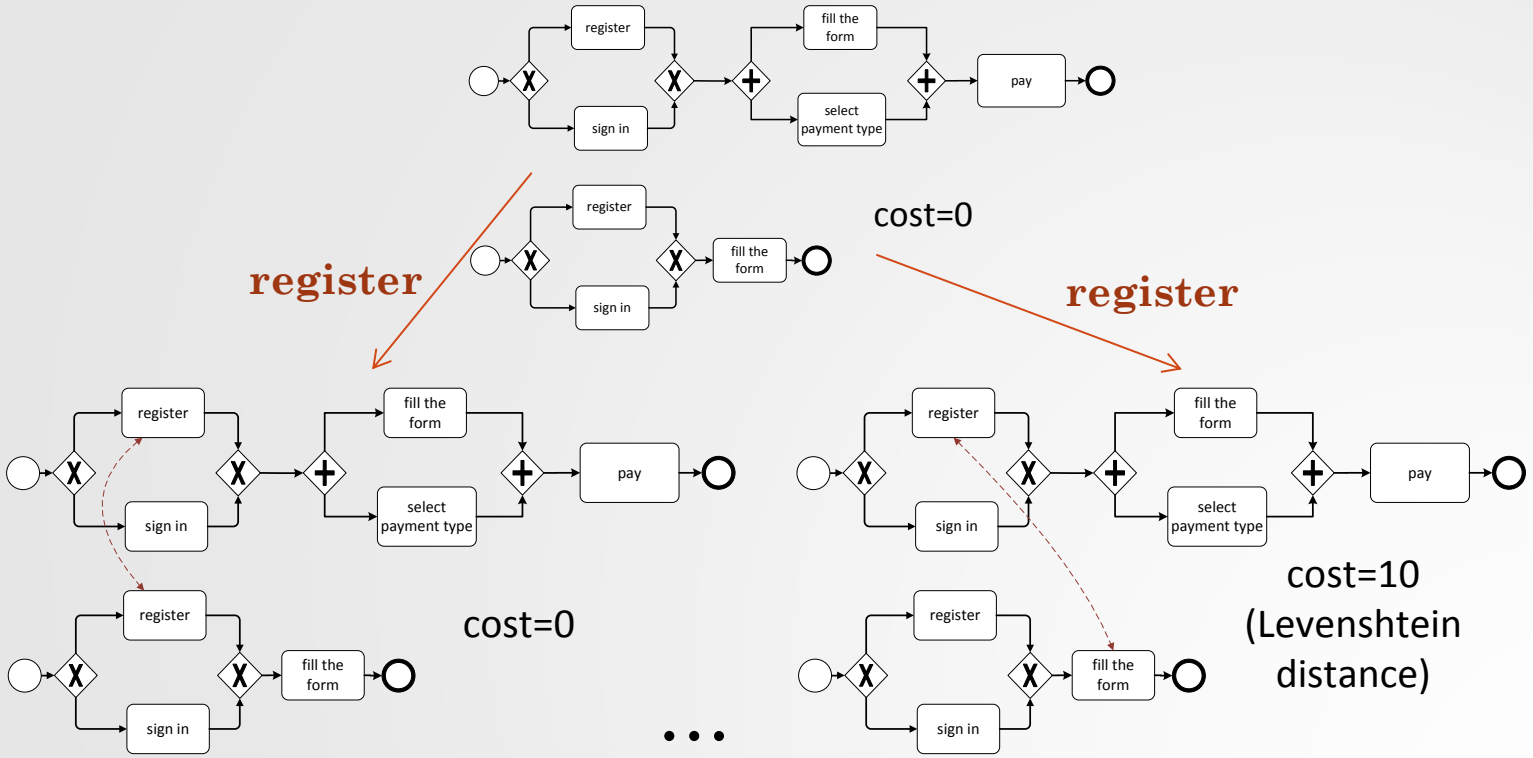
Finding Minimal Graph Edit Distance



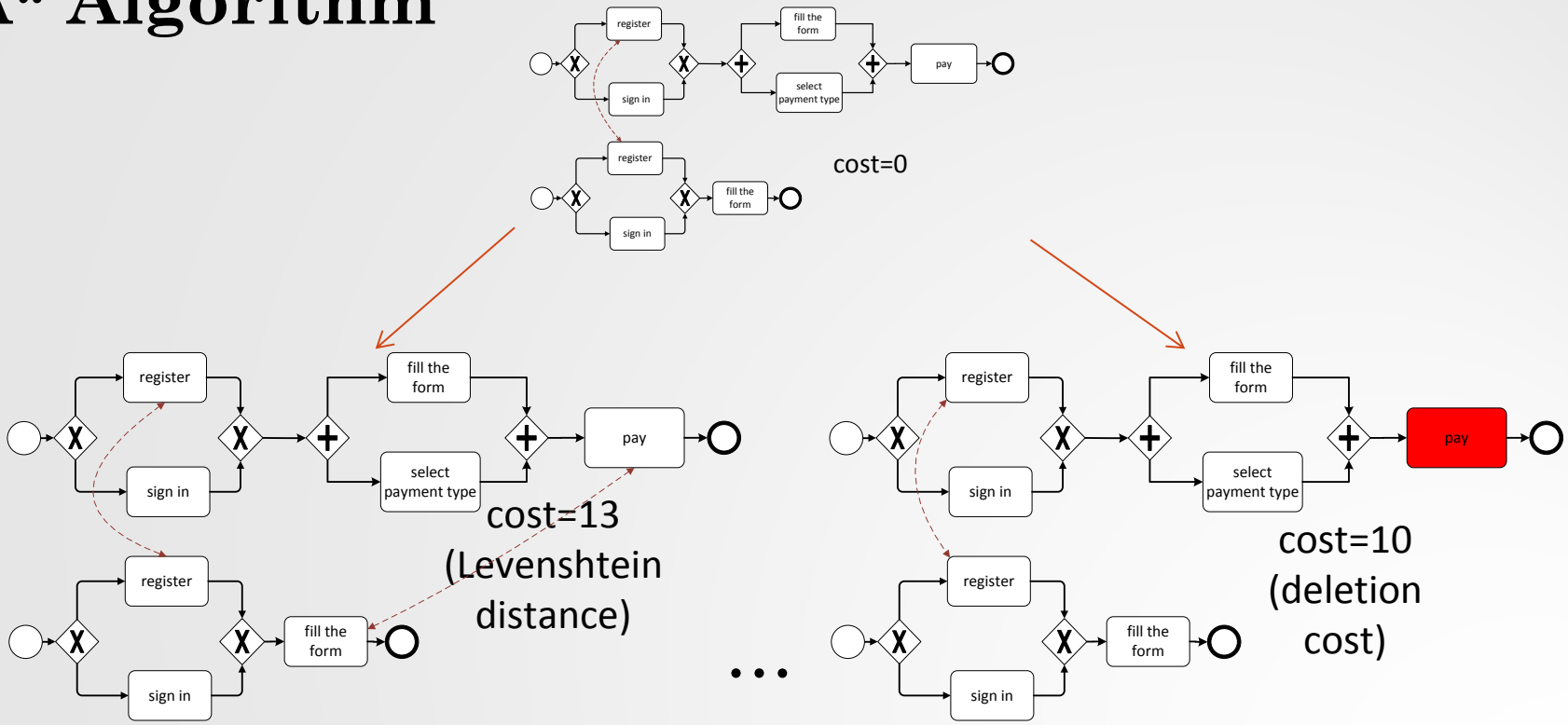




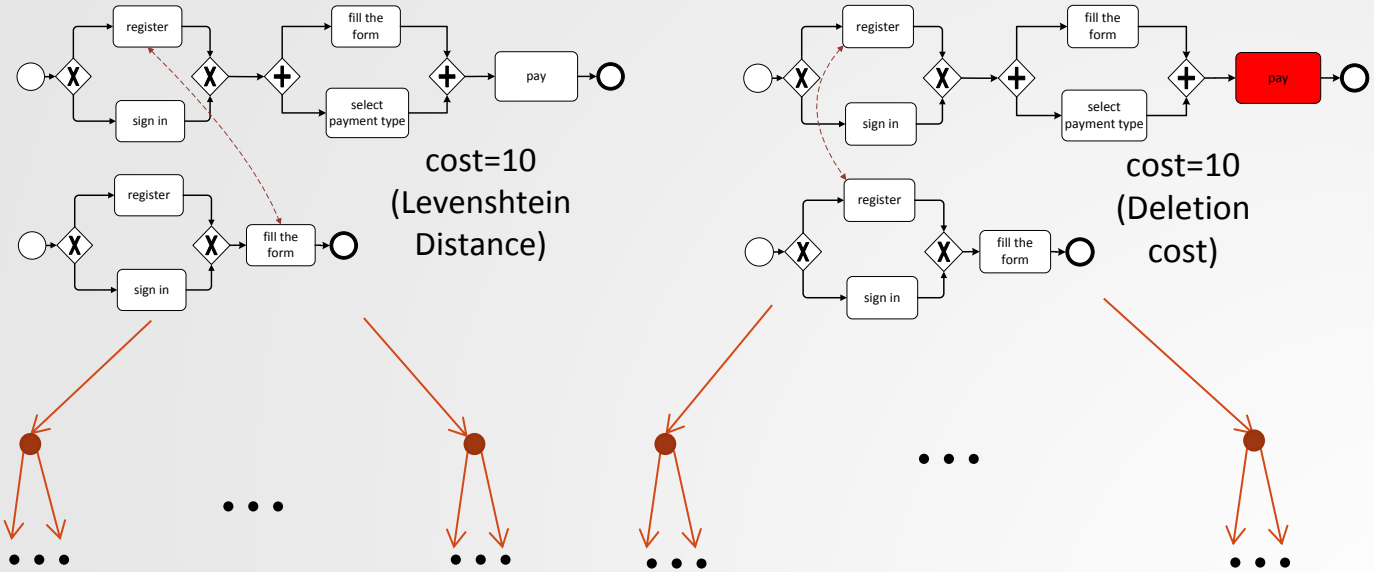
A* Algorithm


register
fill the form
pay
sign in
select payment type
register
fill the form
sign in
cost=0
register
register
register
fill the form
pay
sign in
select payment type
register
fill the form
sign in
cost=0
register
fill the form
pay
sign in
select payment type
register
fill the form
sign in
cost=10
(Levenshtein distance)
• • •

A* Algorithm

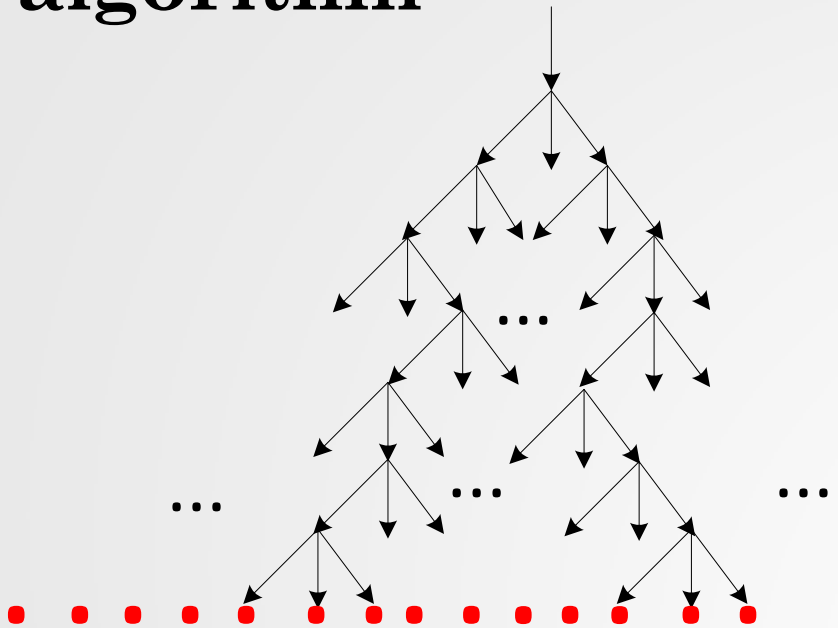

register
sign in
fill the form
select payment type
pay
cost=0
cost=13
(Levenshtein distance)
cost=10
(deletion cost)
...

A* Algorithm



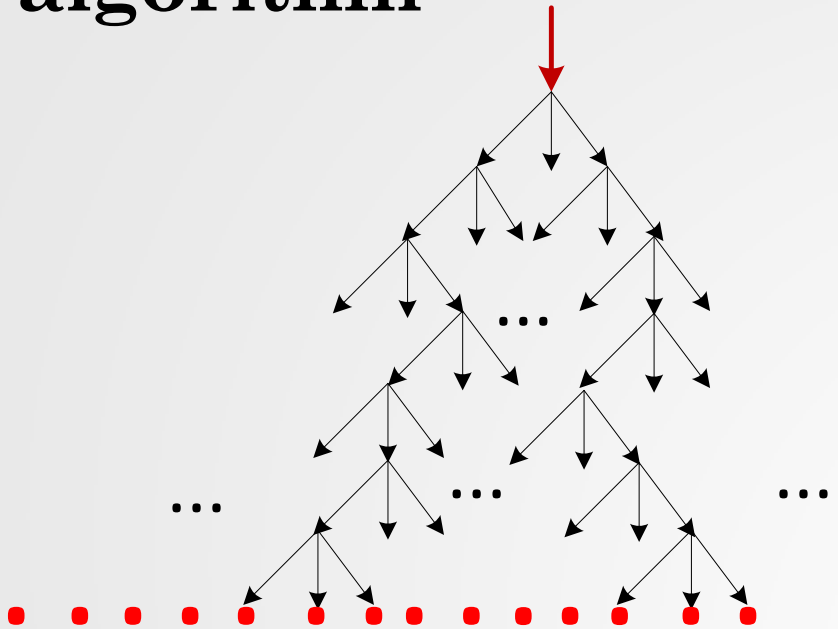
NP problem

Greedy algorithm



Possible solutions

Greedy algorithm



Possible solutions

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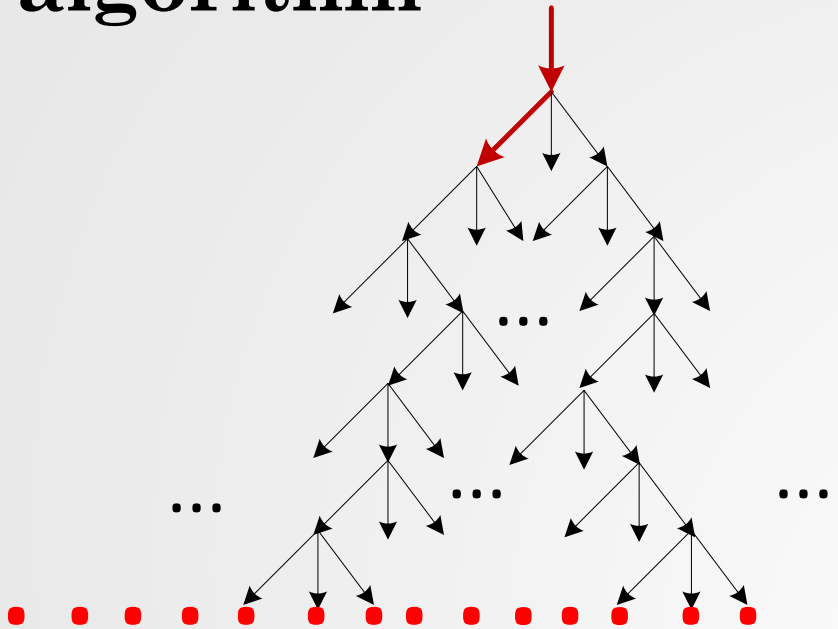
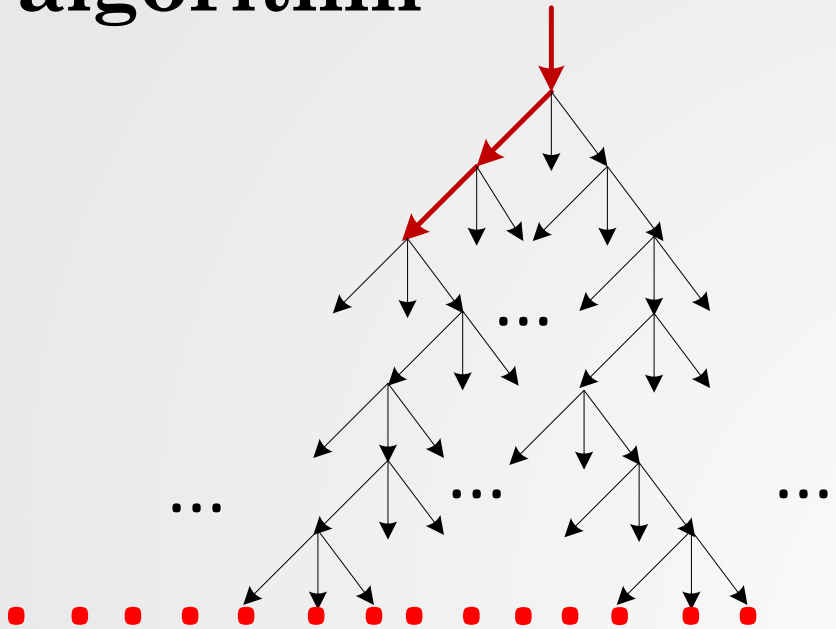


Possible solutions

Greedy algorithm



Possible solutions

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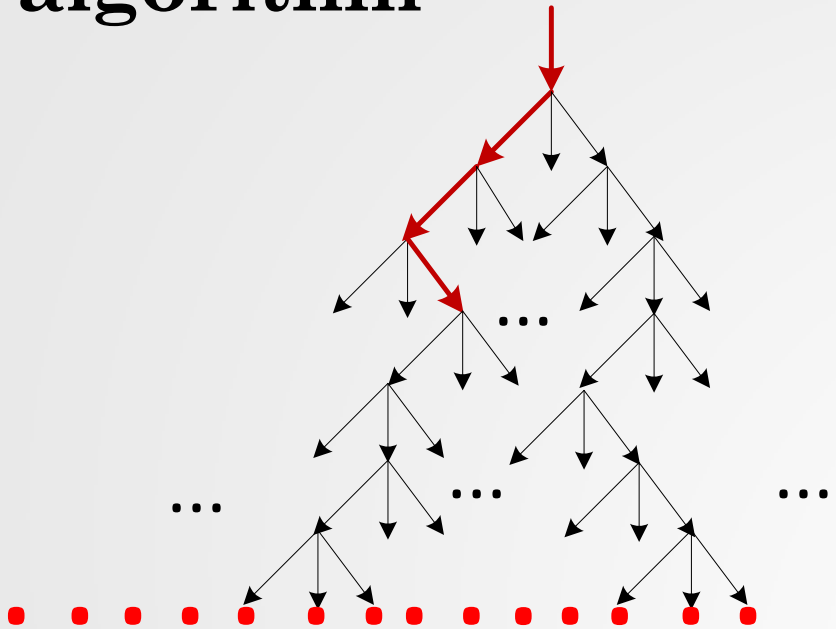

Possible solutions

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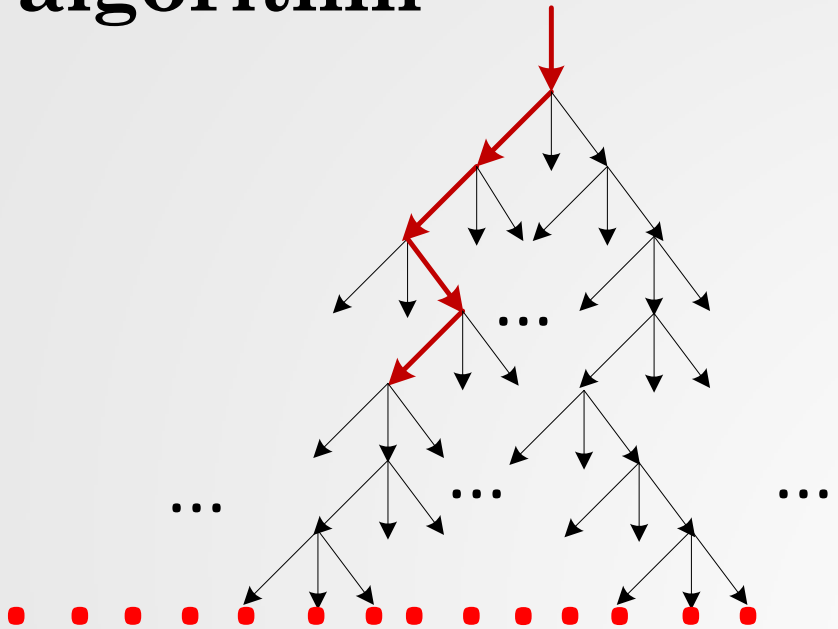

Possible solutions

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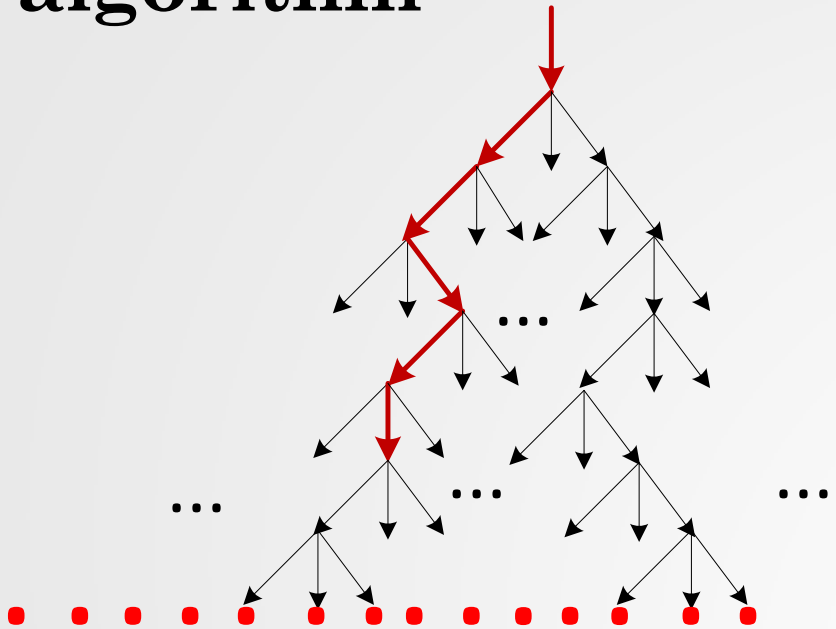

Possible solutions

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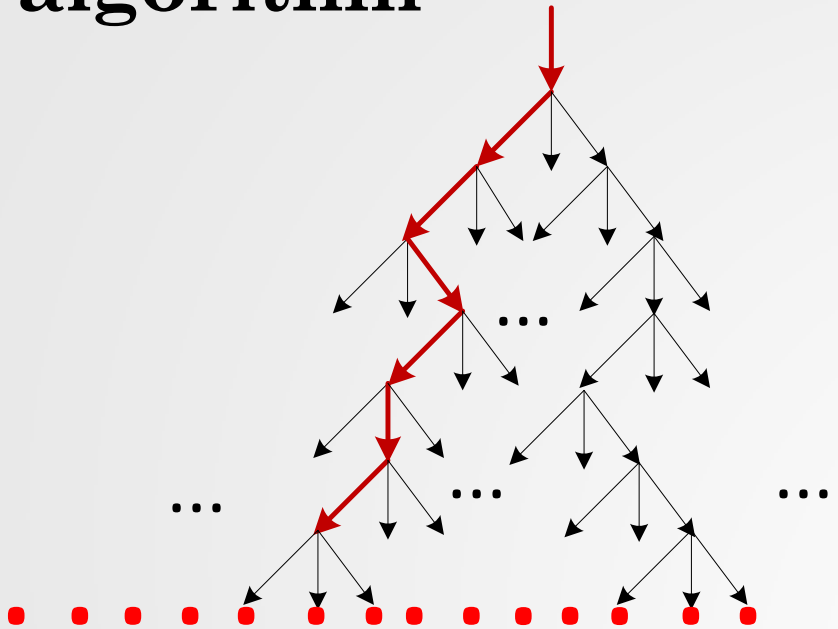

Possible solutions

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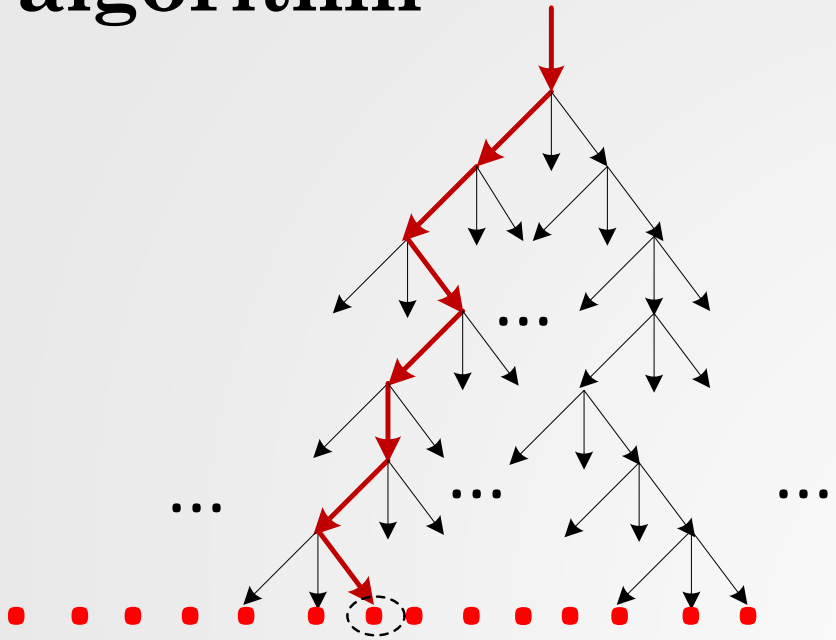
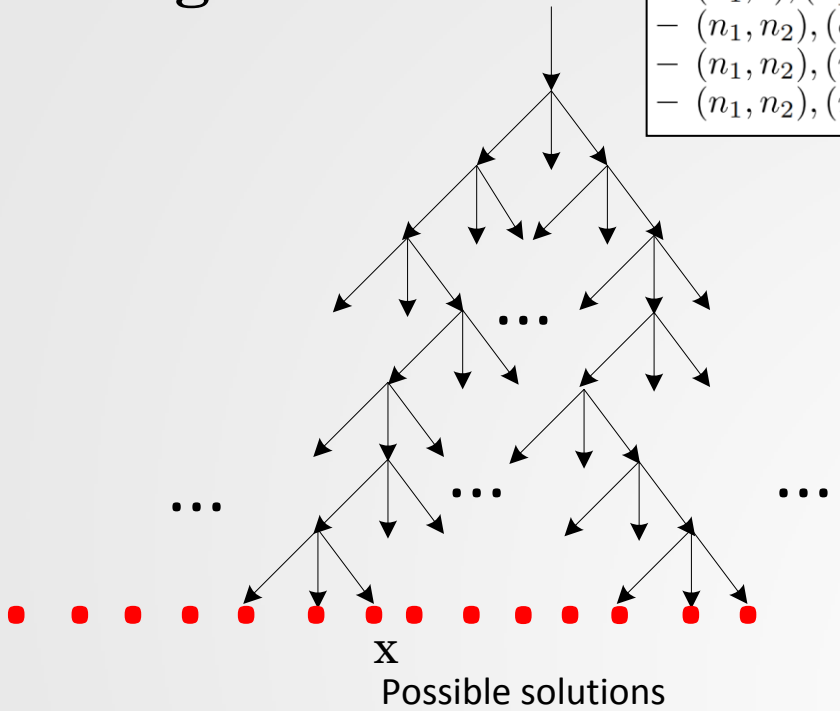


Possible solutions

Tabu search algorithm

- $(n_1, n_2) \rightarrow (n_1, \epsilon), (\epsilon, n_2)$,
- $(n_1, \epsilon), (\epsilon, n_2) \rightarrow (n_1, n_2)$,
- $(n_1, \epsilon), (n_1', n_2) \rightarrow (n_1, n_2), (n_1', \epsilon)$,
- $(n_1, n_2), (\epsilon, n_2') \rightarrow (n_1, n_2'), (\epsilon, n_2)$,
- $(n_1, n_2), (n_1', n_2') \rightarrow (n_1, n_2'), (\epsilon, n_2), (n_1', \epsilon)$,
- $(n_1, n_2), (n_1', n_2') \rightarrow (n_1, \epsilon), (n_1', n_2), (\epsilon, n_2')$.



Tabu list =<x>

Tabu search algorithm

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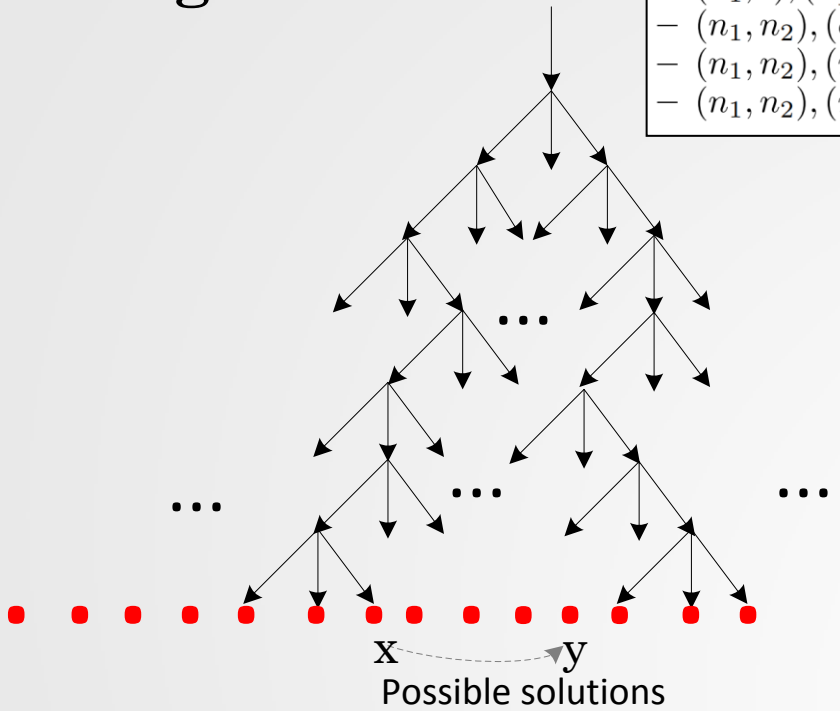

Tabu list =<x, y>

Tabu search algorithm

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- $(n_1, \epsilon), (\epsilon, n_2) \rightarrow (n_1, n_2)$,
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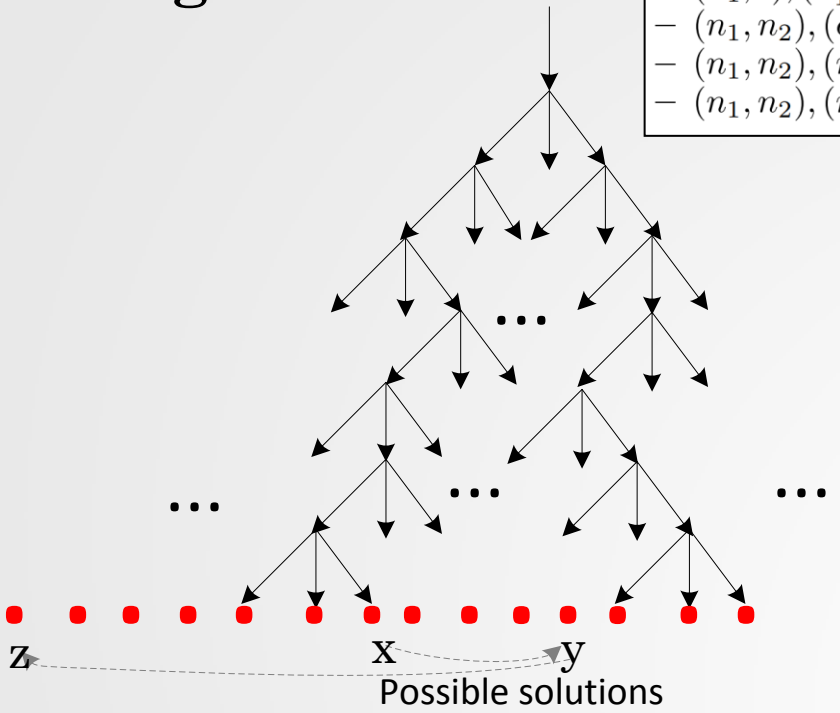
- $(n_1, n_2), (n_1', n_2') \rightarrow (n_1, \epsilon), (n_1', n_2), (\epsilon, n_2')$.



Tabu list =<x, y, z>

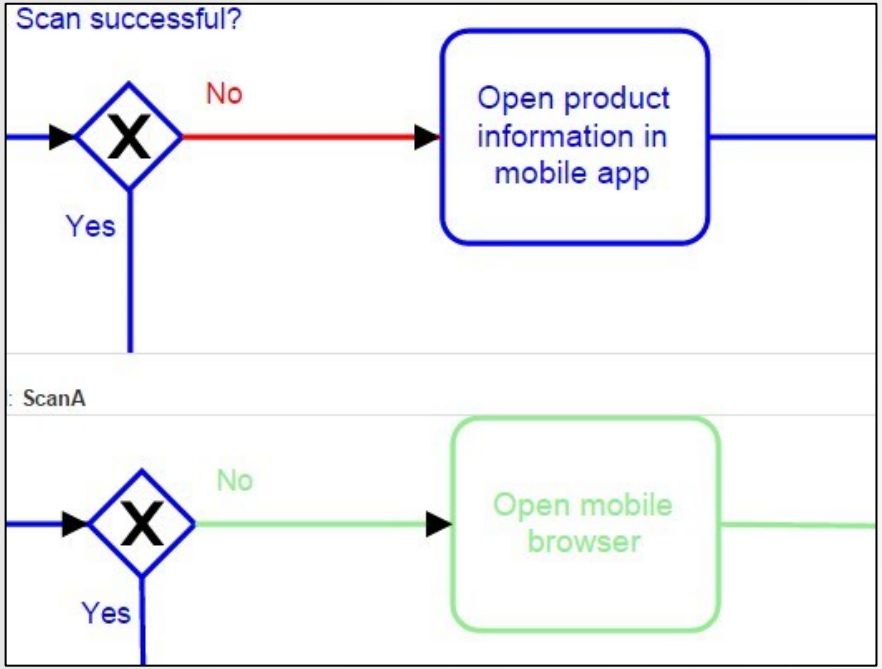
Simulated Annealing algorithm

Data: $G_1 = (N_1, E_1, t_1, l_1)$ and $G_2 = (N_2, E_2, t_2, l_2)$ – business process graphs; $maxTemperature$ – maximal temperature; $temperatureDec$ – temperature decreasing step;
Result: graph edit distance between G_1 and G_2;
initialize R_{cur} – edit relation;
$R_{cur} \leftarrow R_{greedy}$;
$T_{cur} \leftarrow maxTemperature$;
while $(T_{cur} > 0)$ **do**
  $generateOneStepVariants(R_{cur})$;
  $variant \leftarrow takeRandom(oneStepVariants)$;
  if $P(R_{cur}, variant, T_{cur}) \geq random(0, 1)$ **then**
    $R_{cur} \leftarrow variant$;
  end
  $T_{cur} \leftarrow T_{cur} - temperatureDec$;
end
return $cost(R_{cur})$;

Ant Colony algorithm

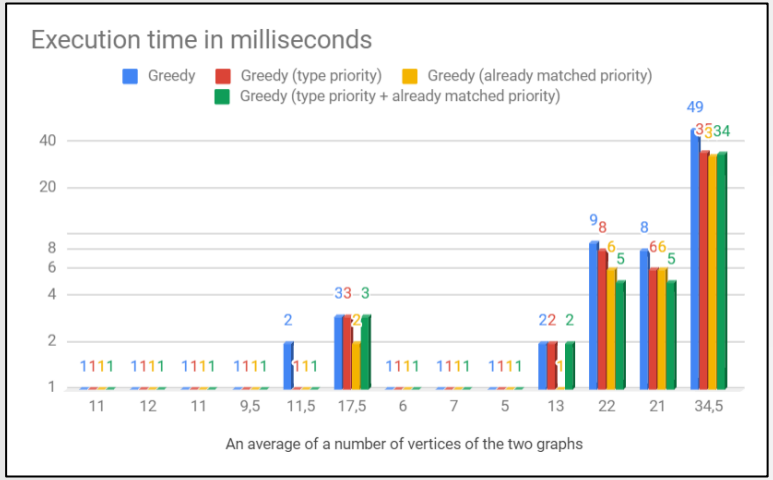
1. Initialize pheromone map with the initial value
2. Generate N ants; each ant does the following:
    1. Generates all the possible vertex replacements for the current state
    2. Calculates the cost for each vertex replacement by the formulae:
    $$\frac{edgePheromones^{pheromonePower}}{pathCost^{distancePower}}$$
    where $edgePheromones$ – the cost of replacing vertices (taken from the pheromone map);
    $pathCost$ – sum of all the edges and vertex replacements
    3. Selects a random replacement with the probability of each replacement:
    $$\frac{replacementCost}{sumOfAllCosts}$$
    4. Performs steps 1-3 until all the vertices are processed
3. Change all the pheromone values by formulae: $(1 - pheromoneEvaporation) * currentValue$
4. For all solutions from the step 2 do the following:
    1. Increase the pheromone map's value for the replacement by $\frac{distanceCoeff}{replacementCost}$
5. Repeat steps 2-3 predefined number of times

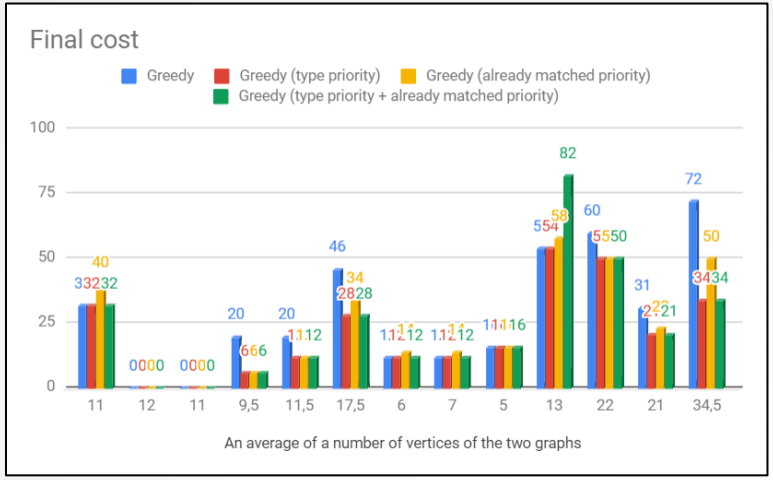
BPMNDiffViz Tool



https://pais.hse.ru/research/projects/CompBPMN

Experimental results. BPMN models discovered from artificial event logs (different algorithms)





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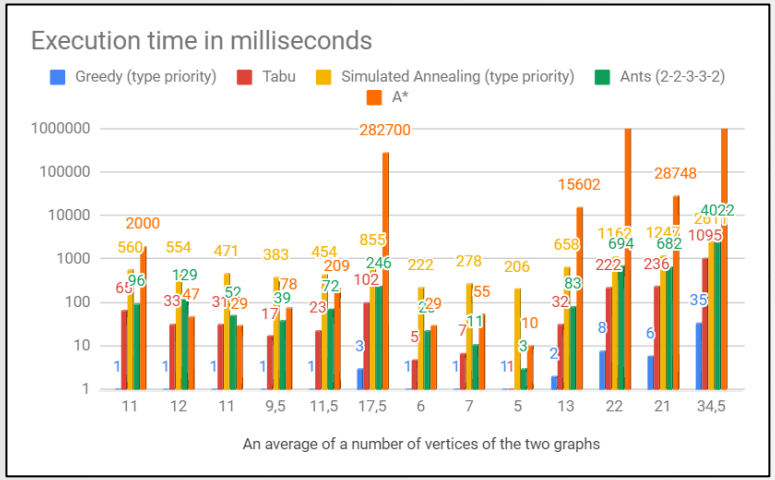
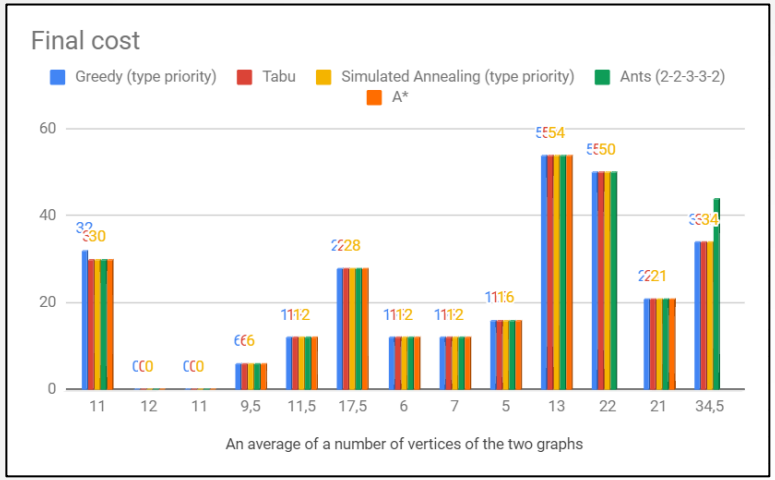
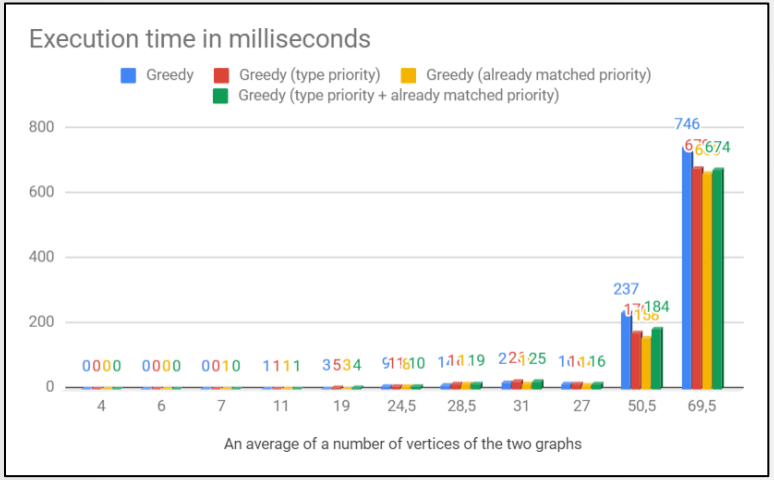
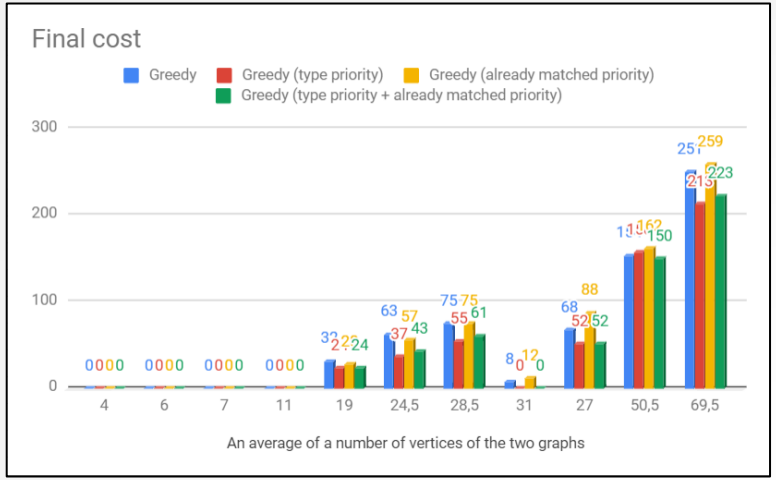




Experimental results. BPMN models discovered from real event logs (different parts of logs)





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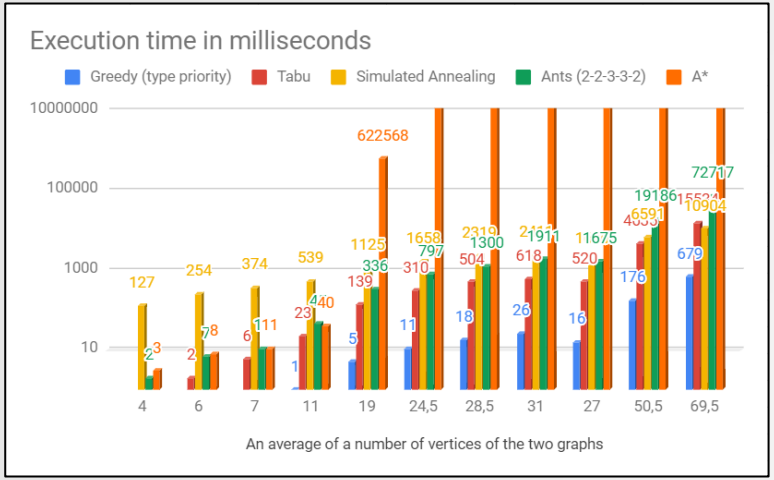

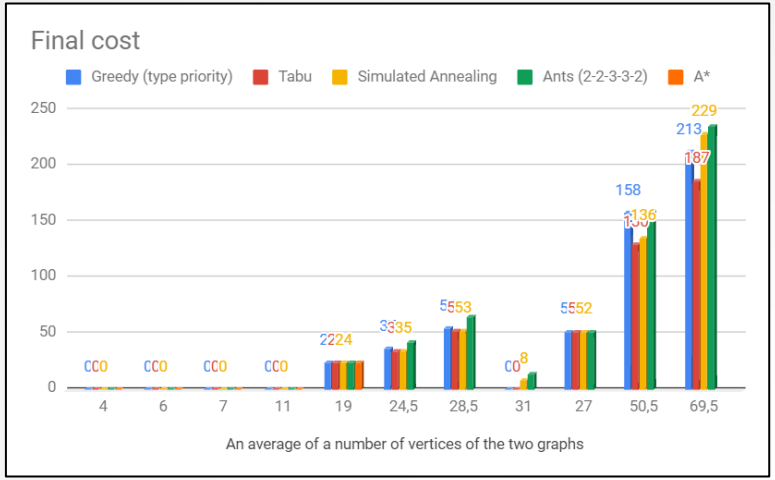

Future work

Industry

- ✓ New suboptimal methods
- ✓ New application fields

Theory

- ✓ Compare with other conformance checking methods
- ✓ Different discovery algorithms (different structure of process models)

Thank you!

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