Recommendation Generation for Performance Improvement by using Cross-Organizational Process Mining

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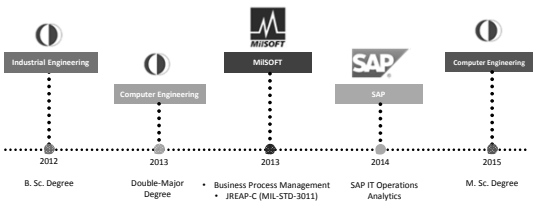

Agenda

1. Introduction
2. Related Work
3. Background
4. Methodology
5. Results & Discussions
6. Conclusion & Future Work
7. Demonstration

Introduction
Process Mining

Relatively young and developing research area and main idea is to

- discover,
- monitor and;
- improve processes by extracting information from event logs. [1]

Events recorded and available

Competitive business life

Introduction
Cross- Organizational Process Mining

Cloud computing and shared infrastructures

Event logs of multiple organizations [2]

Analyze the big picture

Work together to execute the same process

Learn from each other

Execute the same task on shared infrastructure [3]

Introduction
Focus of this Study

- A hybrid approach
  - Using different process mining subfields to create a new point of view
- Cross-organizational process mining
  - Processes are executed on several organizations,
  - Unsupervised learning using performances of organizations

Agenda

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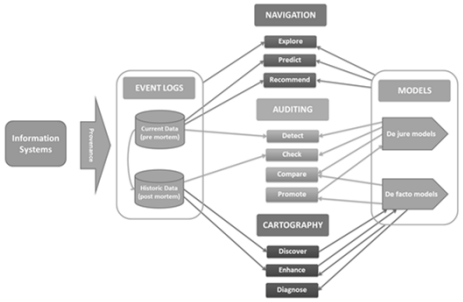
Related Work

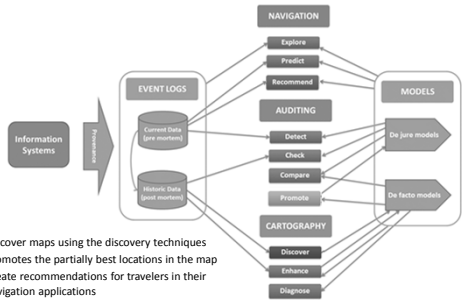
State of the Art in Process Mining



[4]

Related Work

State of the Art in Process Mining



- Discover maps using the discovery techniques
- Promotes the partially best locations in the map
- Create recommendations for travelers in their navigation applications

Related Work
Contributions of This Study

- Cross-organizational process mining approach for process performance improvement
- Generic, noise-capable process mining method for mining process models of different organizations
- Clustering of organizations based on their performance indicators
  - Unlike the clustering methods based on process structures in the literature [9]

Related Work
Contributions of This Study

- Mismatch analysis for spotting differences between processes of organizations
  - Formulation and implementation of patterns and analyzers
- Recommendation generation to show how organizations can learn from other organizations which perform better
- Open-source, extensible and configurable set of plugins in ProM framework

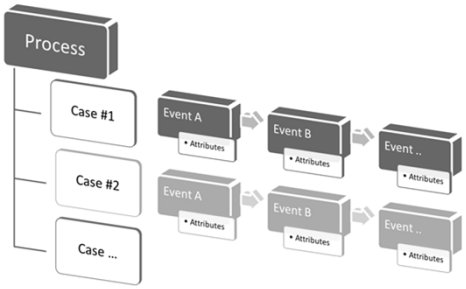
Agenda

Background
Event Log

- Outputs of the software systems like Enterprise Resource Planning (ERP) or Business Process Management (BPM)

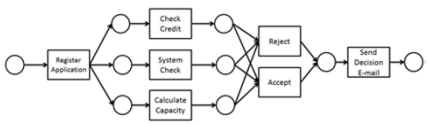
Event Log				
		Attributes		
	Event	Date	Time	Transition
Case #1	Register Application	16.04.2013	14:37:27	Complete
	Check Credit	16.04.2013	14:41:19	Complete
	Check System	16.04.2013	14:47:35	Complete
	Calculate Capacity	16.04.2013	14:50:21	Complete
	Accept	16.04.2013	14:53:22	Complete
	Send decision e-mail	16.04.2013	14:55:11	Complete
Case #2	Register Application	16.04.2013	16:28:19	Complete
	Check Credit	16.04.2013	16:36:22	Complete

Background
Event Log



Background
Process Modeling

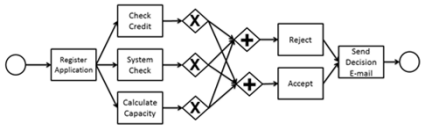
- Workflow Net
  - Petri net with a start node, end node and connectedness



  - Mathematical background

Background
Process Modeling

- Business Process Modelling Notation (BPMN)
  - Standardized and easy to understand by stakeholders



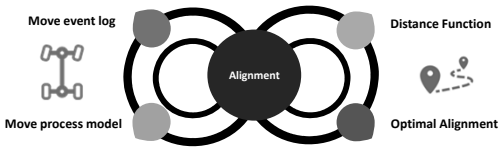
  - Business oriented

Background
Process Discovery

- One of the most challenging tasks is to construct a process model based on the behavior in the event logs
- Inductive Miner Infrequent (*IMi*) is used since it is simple, highly applicable and configurable to handle noise [20]
  - Block-structured Workflow Nets
  - Rediscoverability

Background
Process Performance Analysis

- Discover relationships between event logs and process models for conformance and performance analysis [21]



Background
Mismatch Patterns in Process Models

- Patterns for frequent mismatches between the similar process models by Dijkman [14]

Authorization

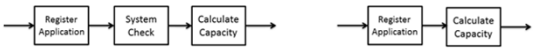
Activity
- Skipped Activity
- Refined Activity

Control Flow
- Activities at Different Moments in Processes
- Different Conditions for Occurrence
- Different Dependencies
- Additional Dependencies

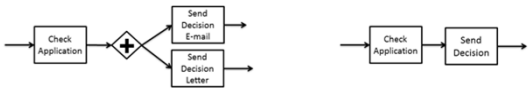
Background
Mismatch Patterns in Process Models

Activity Mismatch Patterns [14]

- Skipped Activity



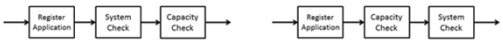
- Refined Activity



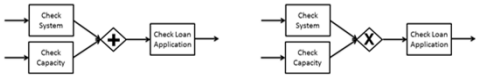
Background
Mismatch Patterns in Process Models

Control Flow Mismatch Patterns [14]

- Activities at Different Moments in Processes



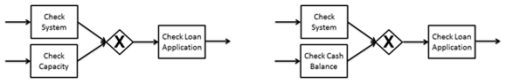
- Different Conditions for Occurrence



Background
Mismatch Patterns in Process Models

Control Flow Mismatch Patterns [14]

- Different Dependencies



- Additional Dependencies

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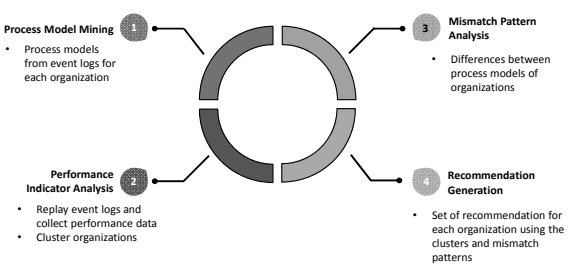
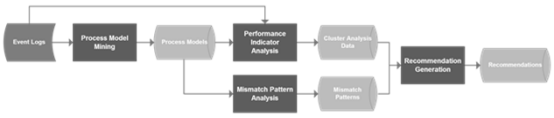
Methodology
Approach Overview

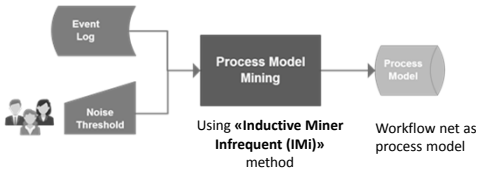


Methodology
Approach Overview



Methodology
Process Model Mining

Applied for each organization:

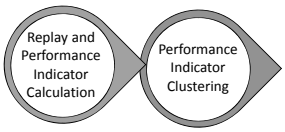


Using **«Inductive Miner Infrequent (IMi)»** method

Workflow net as process model

Methodology
Performance Indicator Analysis

- Two steps:

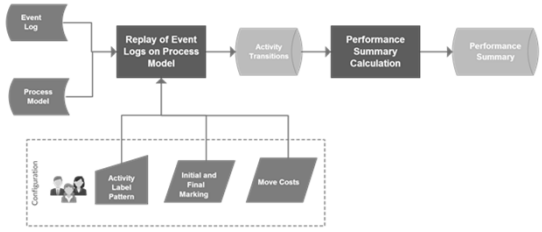


- Performance Indicators:
  - Average Time Between Activities ⇩
  - Standard Deviation of Time Between Activities ⇩

Methodology

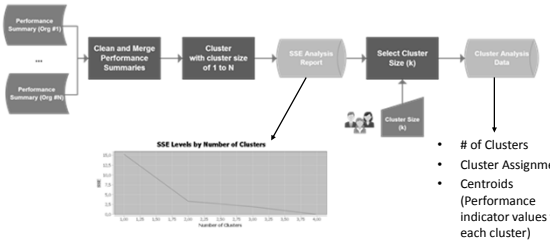
Performance Indicator Analysis - Replay and Performance Indicator Calculation

Applied for each organization:



Methodology

Performance Indicator Analysis – Performance Indicator Clustering

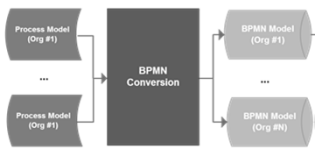


- # of Clusters
- Cluster Assignment
- Centroids (Performance indicator values for each cluster)

Methodology

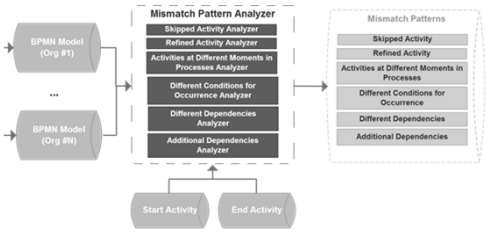
Mismatch Pattern Analysis

- Spot the differences between process models of different organizations as mismatch patterns
- BPMN used since notation is more appropriate to formulate mismatch patterns



Methodology
Mismatch Pattern Analysis

- Mismatch patterns and analyzers are developed

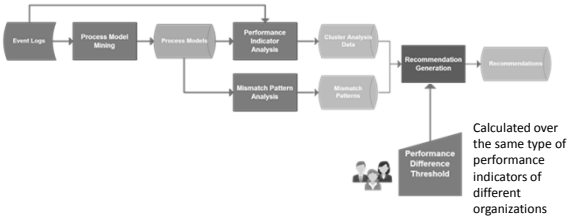


Methodology
Recommendation Generation

- Providing a set of mismatch patterns for each organization to enhance their processes.
  - Mismatch patterns between organizations, which are **performing better** in terms of their performance indicator values.

$$\text{Recommendation} = (\text{Organization}, A_{start}, A_{end}, \text{Mismatch Patterns})$$

Methodology
Recommendation Generation



Calculated over the same type of performance indicators of different organizations

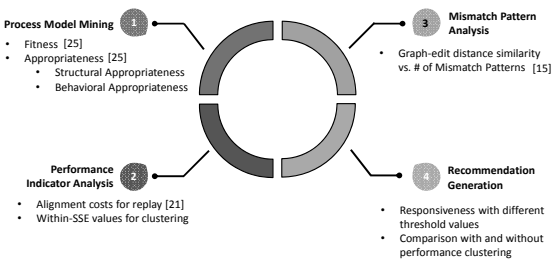
Methodology
Recommendation Generation

```
RecommendationGeneration
input: O organization, C Cluster Analysis Data, P performance
difference threshold
output: Recommendations a set of recommendations

Recommendations ← {}
i ← Cluster of organization O
for each centroid for cluster i
  Get other cluster j with the centroids of A_start and A_end; and
  value difference larger than P
  for each organization O' in the cluster j
    MismatchPatterns ←  Mismatch Pattern Analysis(O, O',A_start, A_end)
    Recommendations ←  Recommendation(O, A_start,A_end, MismatchPatterns)
```


Agenda

Results & Discussions
Evaluation Metrics



Results & Discussions
Dataset Selection

- **Loan Application Process** [26]
  - Synthetically generated
  - 4 variants of a simple loan application in a financial institute
- **Environmental Permit Application Process** [27]
  - Real-life event log from "Configurable Services for Local Governments (CoSeLoG)" project [13]
  - «Environmental Permit Application Process» of 5 municipalities in Netherlands

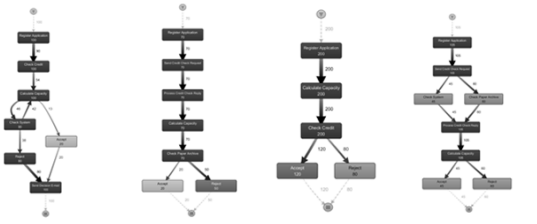
Results & Discussions
Loan Application Process

	Cases	Events	Percentage
Variant #1	100	590	24 %
Variant #2	70	420	17 %
Variant #3	200	800	33 %
Variant #4	105	630	26 %

Cases 475 Events 2440

- These variants are used as organizational logs

Results & Discussions
Loan Application Process – Process Model Mining

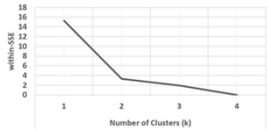


Variant #1	Variant #2	Variant #3	Variant #4
100 % (Fitness)	100 % (Fitness)	100 % (Fitness)	100 % (Fitness)
84.2 % (Avg. App.)	100 % (Avg. App.)	100 % (Avg. App.)	99.1 % (Avg. App.)

Results & Discussions

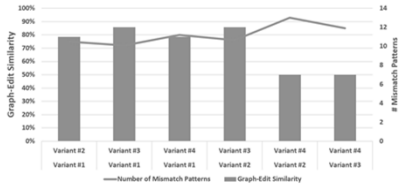
Loan Application Process – Performance Indicator Analysis

- **Clustering:**



Results & Discussions

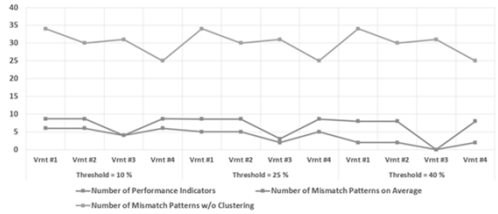
Loan Application Process – Mismatch Pattern Analysis



Correlation between graph-edit similarity and number of mismatch patterns

Results & Discussions

Loan Application Process – Recommendation Generation



- Responsiveness and degree of helping the user to focus on the performance improvement

Results & Discussions

Environmental Permit Application Process

	Cases	Events	Percentage
Municipality #1	54	131	6.1 %
Municipality #2	302	586	27.3 %
Municipality #3	37	73	3.4 %
Municipality #4	340	507	23.7 %
Municipality #5	481	845	39.4 %

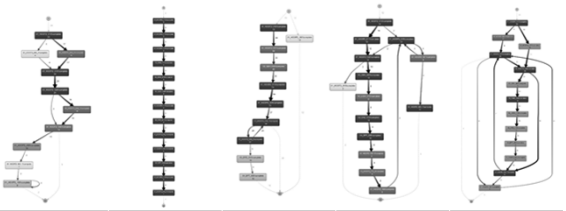
Cases 1214 Events 2142

- Preprocessing is undertaken on the raw dataset [28]
- These municipalities are used as organizational logs

Results & Discussions

Environmental Permit Application Process – Process Model Mining

- 10 to 20 times simplified process models

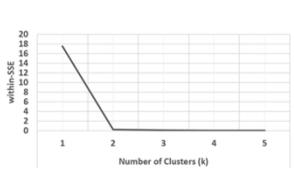


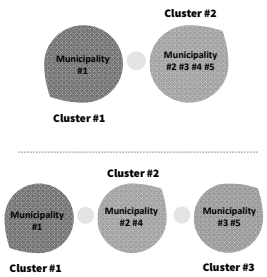
Municipality #1	Municipality #2	Municipality #3	Municipality #4	Municipality #5
86 % (Fitness)	100 % (Fitness)	92.3 % (Fitness)	96.8 % (Fitness)	94.5 % (Fitness)
76 % (Avg. App.)	100 % (Avg. App.)	69.1 % (Avg. App.)	64.9 % (Avg. App.)	49.3 % (Avg. App.)

Results & Discussions

Environmental Permit Application Process – Performance Indicator Analysis

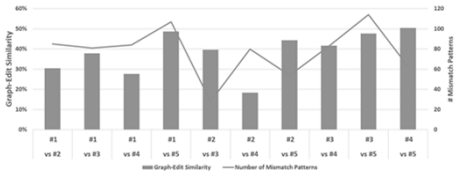
- **Clustering:**





Results & Discussions

Environmental Permit Application Process – Mismatch Pattern Analysis

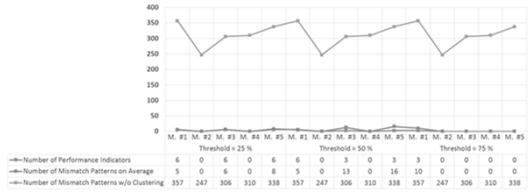


- Correlation between graph-edit similarity and number of mismatch patterns except Municipality #4 and #5

Results & Discussions

Environmental Permit Application Process – Recommendation Generation

(with 3 clusters)



	M. #1	M. #2	M. #3	M. #4	M. #5	M. #1	M. #2	M. #3	M. #4	M. #5	M. #1	M. #2	M. #3	M. #4	M. #5
Number of Performance Indicators	6	0	6	0	6	6	0	3	0	3	3	0	0	0	0
Number of Mismatch Patterns on Average	5	0	6	0	8	5	0	13	0	16	10	0	0	0	0
Number of Mismatch Patterns w/o Clustering	357	247	306	310	338	357	247	306	310	338	357	247	306	310	338

- Learning opportunities increases as number of cluster increases
- Number of mismatch patterns to check significantly decreases with performance clustering

Results & Discussions

Discussions

- Mismatch analysis stage:
  - Differences in accordance with similarity metrics
  - Information value of mismatch patterns are not equal
- Recommendation generation stage:
  - Performance clustering helps to focus on differences
    - 3 times less in Loan Application Process Dataset
    - 100 times less in Environmental Permit Application Process Dataset

Results & Discussions
Discussions

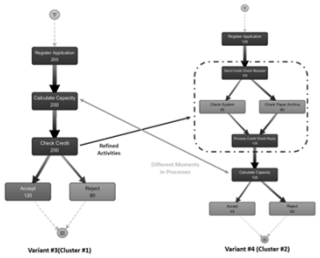
- Business value of generated recommendations:
  - Results may be
    - important or
    - infeasible and irrelevant for business environment
  - Some insights about results can be provided but business environment and case related assessment is important.

Results & Discussions
Discussions

In Loan Application Process, Variant #4 performs better
- 27 % on average time and
- 12 % on standard deviation time

between activities

Calculate Capacity → Accept



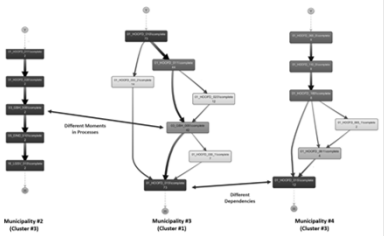
Process models between activities «Calculate Capacity» and «Accept»

Results & Discussions
Discussions

In Environmental Permit Application Process, Municipality #3 performs worse
- 40 % on average time and
- 53 % on standard deviation time

between activities

01_HOOFD_010 → 01_HOOFD_015



Simplified process models between activities «01_HOOFD_010» and «01_HOOFD_015»

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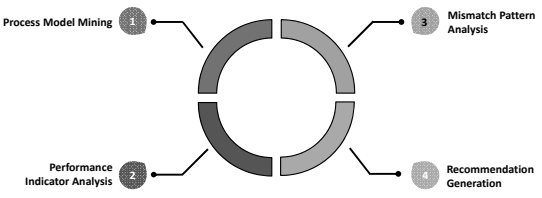
Conclusion

- Cross-organizational process mining is applied
  - Unsupervised learning with predictor variables as performances of organizations
  - In an environment where processes are executed on several organizations
- Results show that it is possible to use cross-organizational process mining and mismatch patterns for performance improvement recommendations

Conclusion

- A four-stage solution is presented and their performances are explained



Conclusion
Future Work

- Process mining stage:
  - Different techniques can be used to mine complex process models
- Performance indicator stage:
  - New indicators based on business environment and needs

Conclusion
Future Work

- Mismatch pattern analysis:
  - New patterns can be introduced
- Recommendation generation:
  - Domain or BPM expertise to assess the quality of recommendations

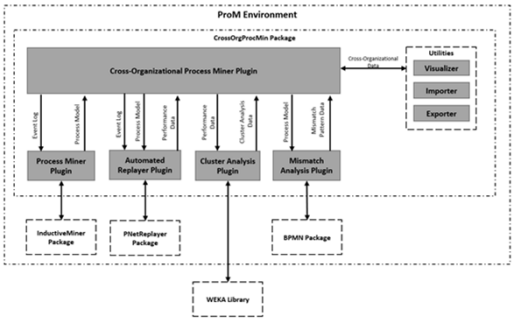
Agenda

ProM Implementation

- ProM, extensible framework that supports a wide variety of process mining techniques in form of plugins [24]
- Widely accepted in industry and academia with an active community
- Developed set of plugins are packaged with the name of **«CrossOrgProcMin»** and published on Github.

onuryilmaz/cross-orc-proc-min

ProM Implementation



Demonstration

ProM process mining workbench

YouTube

Also available on YouTube
http://youtu.be/T92UrRfl3r0

References

[1] W. M. P. van der Aalst, A. Adriansyah, A.K.A. de Medeiros, and et al. Process mining manifesto. In Business process management workshops, pages 169–194. Springer, 2012.
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Questions & Comments

Thank you for your attention!

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