UNIVERSITÀ DEGLI STUDI DI BARI ALDO MORO

Formal Methods - Case study on Process Mining with PN

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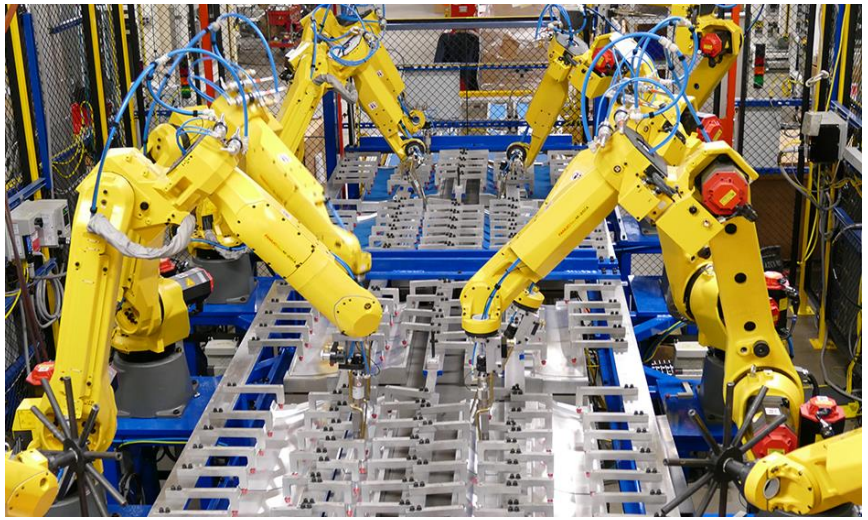
Goal of case of study



The objective of the case study is to analyse a set of logs of an assembly line of a company of different products.

Then apply different process mining algorithms to obtain different process models to help understand real process.

Dataset

The dataset contains information related to product processes in an assembly line.

The dataset consists of 14 columns and 4543 instances of which 221 are products with different activities.

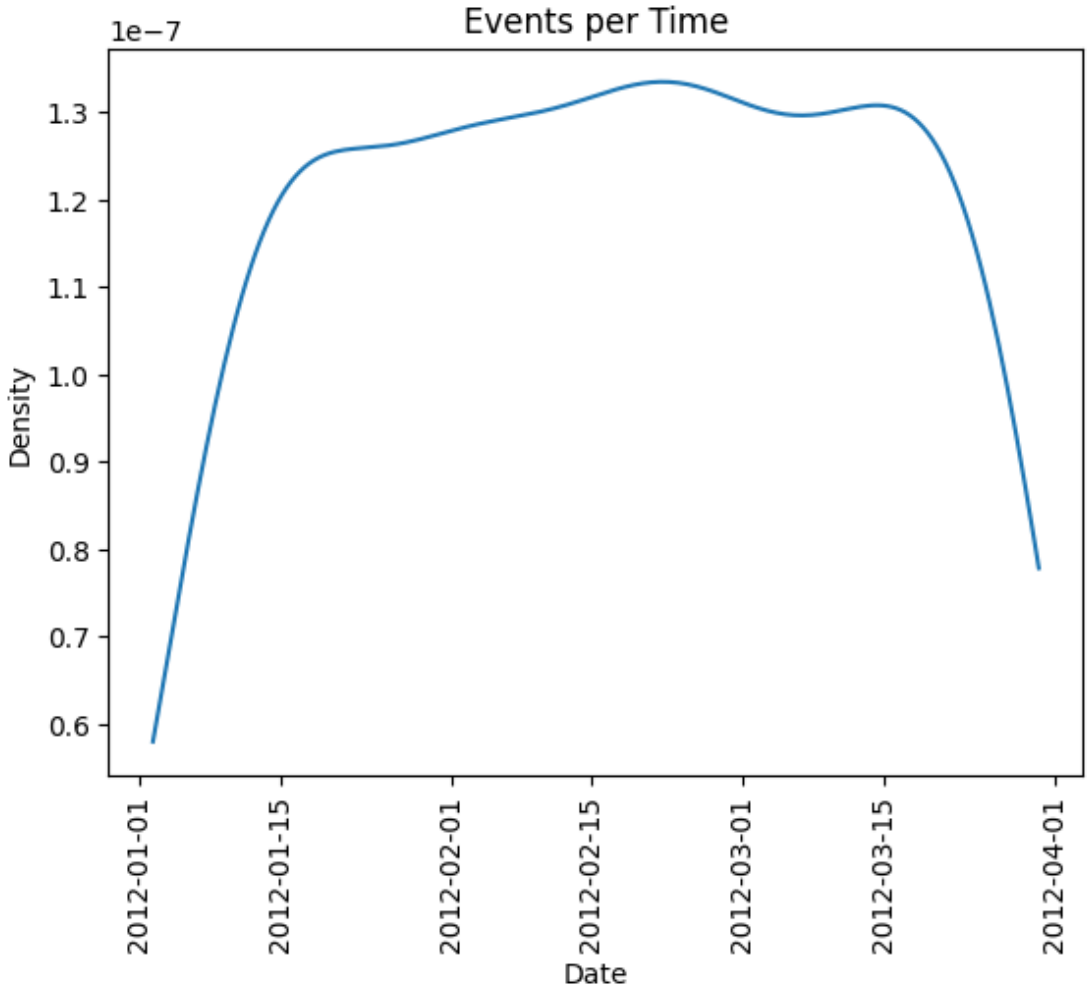
Log analysis

	Case ID	Activity	Resource	Start Timestamp	Complete Timestamp
0	Case 1	Turning & Milling - Machine 4	Machine 4 - Turning & Milling	2012/01/29 23:24:00.000	2012/01/30 05:43:00.000
1	Case 1	Turning & Milling - Machine 4	Machine 4 - Turning & Milling	2012/01/30 05:44:00.000	2012/01/30 06:42:00.000
2	Case 1	Turning & Milling - Machine 4	Machine 4 - Turning & Milling	2012/01/30 06:59:00.000	2012/01/30 07:21:00.000
3	Case 1	Turning & Milling - Machine 4	Machine 4 - Turning & Milling	2012/01/30 07:21:00.000	2012/01/30 10:58:00.000
4	Case 1	Turning & Milling Q.C.	Quality Check 1	2012/01/31 13:20:00.000	2012/01/31 14:50:00.000

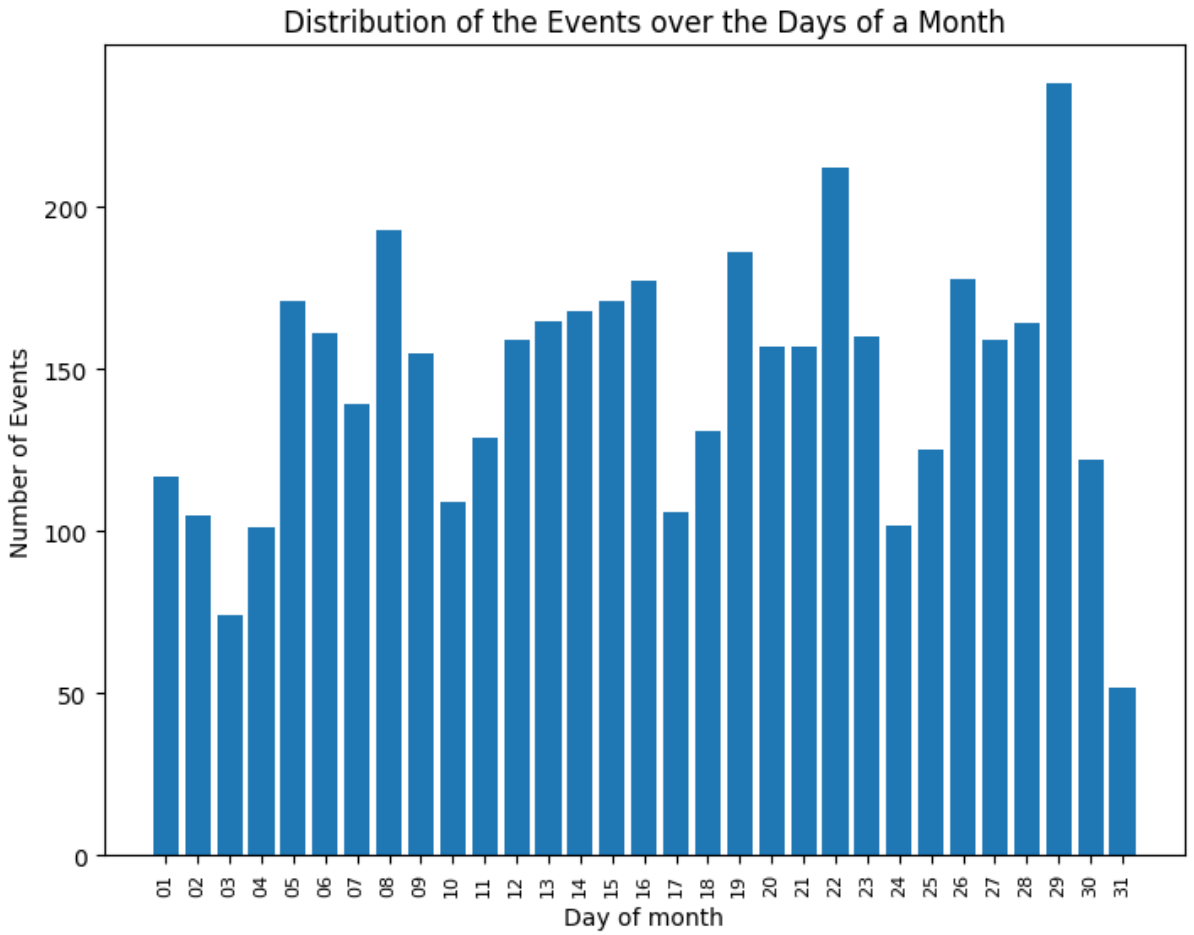
Span	Work Order Qty	Part Desc.	Worker ID	Report Type	Qty Completed	Qty Rejected	Qty for MRB	Rework
006:19	10	Cable Head	ID4932	S	1	0	0	NaN
000:58	10	Cable Head	ID4932	D	1	0	0	NaN
000:22	10	Cable Head	ID4167	S	0	0	0	NaN
003:37	10	Cable Head	ID4167	D	8	0	0	NaN
001:30	10	Cable Head	ID4163	D	9	1	0	NaN

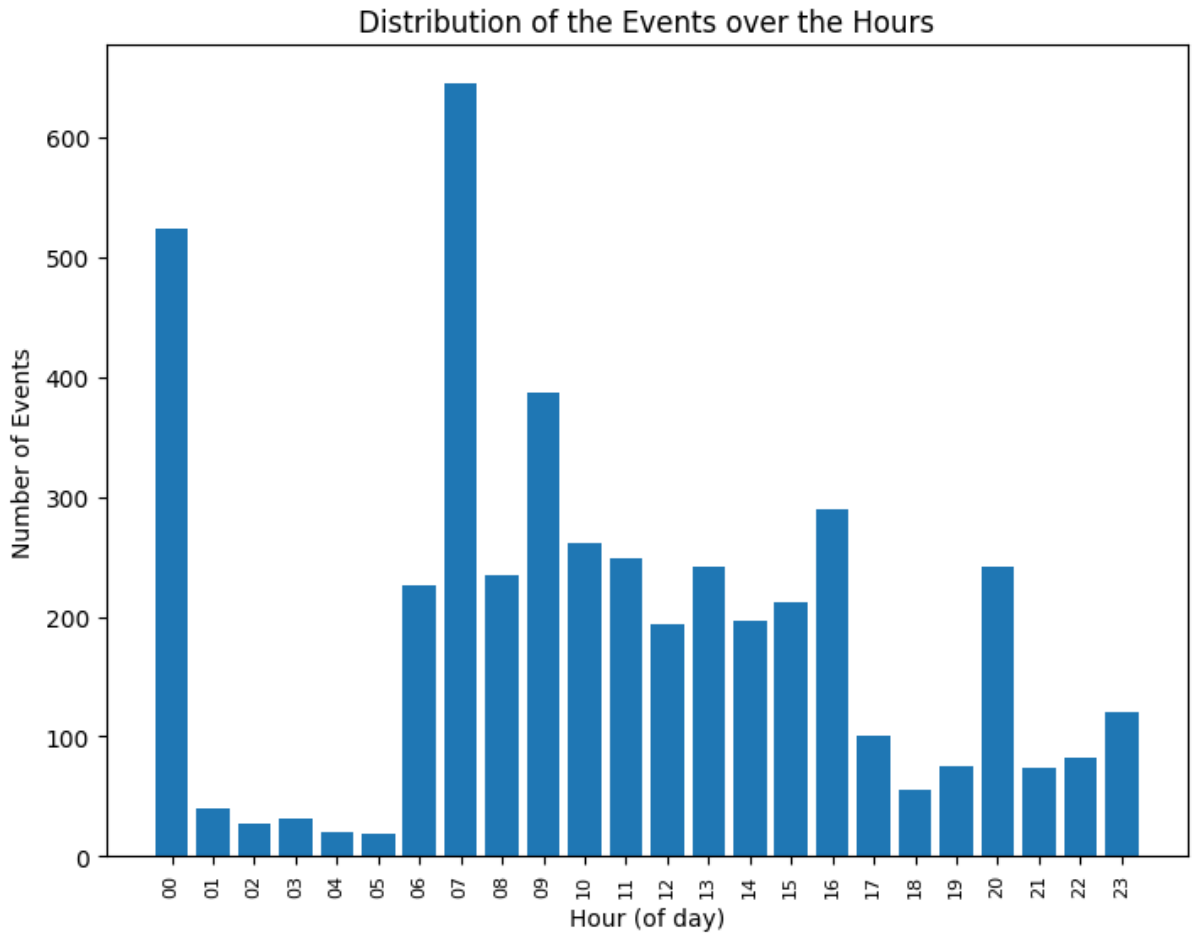
Log analysis

Activity	Days	Hours	Minutes	Seconds
Change Version - Machine 22	0	8	11	45
Deburring - Manual	0	2	9	53
Final Inspection - Weighting	0	1	15	0
Final Inspection Q.C.	0	1	54	48
Fix - Machine 15	0	1	19	30
Fix - Machine 15M	0	1	36	0
Fix - Machine 19	0	6	45	0
Fix - Machine 3	0	1	17	0
Fix EDM	0	2	45	15
Flat Grinding - Machine 11	0	1	33	29
Flat Grinding - Machine 26	0	4	30	0
Grinding Rework	0	1	38	49
Grinding Rework - Machine 12	0	2	2	43
Grinding Rework - Machine 2	0	5	44	50
Grinding Rework - Machine 27	0	2	37	3
Lapping - Machine 1	0	1	46	32
Laser Marking - Machine 7	0	0	57	45
Milling - Machine 10	0	1	15	0
Milling - Machine 14	0	4	22	53
Milling - Machine 16	0	7	37	18
Milling - Machine 8	0	7	59	0
Milling Q.C.	0	1	15	0
Nitration Q.C.	0	0	26	15
Packing	0	1	0	0
Rework Milling - Machine 28	0	1	45	0
Round Q.C.	0	1	7	30
Round Grinding - Machine 12	0	2	53	17
Round Grinding - Machine 19	0	2	16	20
Round Grinding - Machine 2	0	3	53	28
Round Grinding - Machine 23	0	2	33	40
Round Grinding - Machine 3	0	3	50	0
Round Grinding - Manual	0	3	35	42
Round Grinding - Q.C.	0	2	25	19
SETUP Turning & Milling - Machine 5	0	3	20	40
Setup - Machine 4	0	1	53	0
Setup - Machine 8	0	1	16	0
Stress Relief	0	2	0	0
Turn & Mill. & Screw Assem - Machine 10	0	5	51	57
Turn & Mill. & Screw Assem - Machine 9	0	3	9	42
Turning & Milling - Machine 10	0	5	38	6
Turning & Milling - Machine 4	0	5	33	43
Turning & Milling - Machine 5	0	5	23	8
Turning & Milling - Machine 6	0	5	5	22
Turning & Milling - Machine 8	0	3	42	40
Turning & Milling - Machine 9	0	4	49	9
Turning & Milling Q.C.	0	1	31	37
Turning - Machine 21	0	4	30	0
Turning - Machine 4	0	6	29	7
Turning - Machine 5	0	3	39	30
Turning - Machine 8	0	3	53	10
Turning - Machine 9	0	4	19	10
Turning Q.C.	0	1	28	4
Turning Rework - Machine 21	0	2	30	0
Wire Cut - Machine 13	0	5	38	22
Wire Cut - Machine 18	0	5	0	0



Log analysis





Log analysis

Number of variants: 221

Example of variants:

- *Turning & Milling - Machine 4 --> Turning & Milling - Machine 4 --> Turning & Milling - Machine 4 --> Turning & Milling - Machine 4 --> Turning & Milling Q.C. --> Laser Marking - Machine 7 --> Lapping - Machine 1 --> Lapping - Machine 1 --> Lapping - Machine 1 --> Lapping - Machine 1 --> Round Grinding - Machine 3 --> Round Grinding - Machine 3 --> Final Inspection Q.C. --> Final Inspection Q.C. --> Final Inspection Q.C. --> Packing*
- *Turning & Milling - Machine 9 --> Turning Q.C. --> Turning & Milling - Machine 9 --> Turning & Milling - Machine 9 --> Turning & Milling - Machine 9 --> Turning & Milling - Machine 9 --> Turning & Milling - Machine 9 --> Turning & Milling - Machine 9 --> Turning & Milling - Machine 9 --> Turning & Milling - Machine 9 --> Turning & Milling - Machine 9 --> Turning & Milling - Machine 9 --> Turning & Milling - Machine 9 --> Turning Q.C. --> Laser Marking - Machine 7 --> Laser Marking - Machine 7 --> Laser Marking - Machine 7 --> Flat Grinding - Machine 11 --> Flat Grinding - Machine 11 --> Flat Grinding - Machine 11 --> Final Inspection Q.C. --> Packing*
- *Turning & Milling - Machine 8 --> Turning & Milling - Machine 8 --> Turning & Milling - Machine 8 --> Turning & Milling - Machine 8 --> Turning & Milling Q.C. --> Laser Marking - Machine 7 --> Flat Grinding - Machine 11 --> Lapping - Machine 1 --> Round Grinding - Machine 3 --> Round Grinding - Machine 3 --> Grinding Rework - Machine 12 --> Final Inspection Q.C. --> Packing --> Final Inspection Q.C.*
- *Setup - Machine 8 --> Turning & Milling - Machine 8 --> Turning & Milling - Machine 8 --> Turning & Milling - Machine 8 --> Turning & Milling - Machine 8 --> Turning & Milling - Machine 8 --> Turning & Milling - Machine 8 --> Turning & Milling Q.C. --> Flat Grinding - Machine 11 --> Lapping - Machine 1 --> Round Grinding - Machine 12 --> Round Grinding - Machine 12 --> Final Inspection Q.C. --> Lapping - Machine 1 --> Laser Marking - Machine 7 --> Packing*

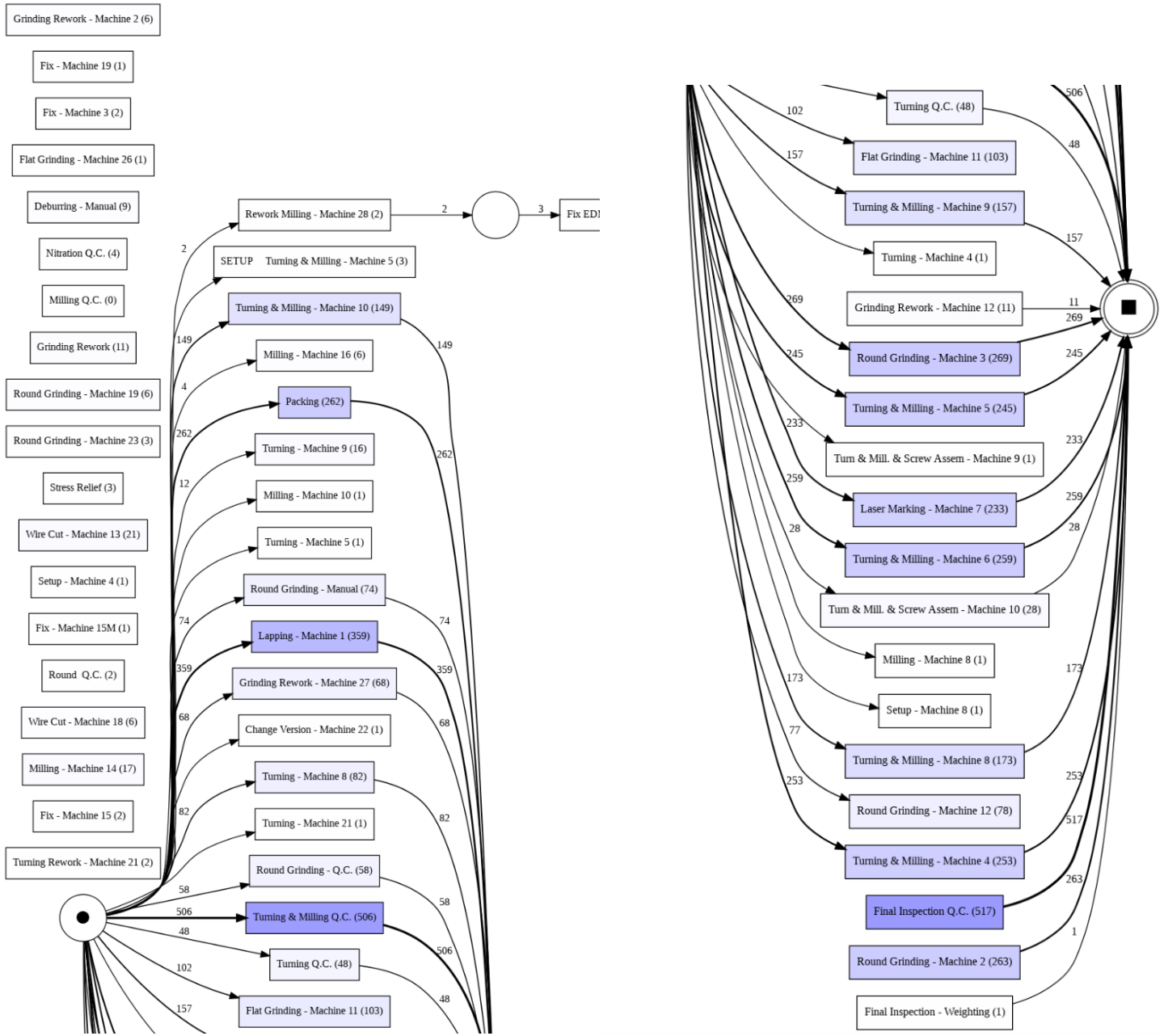
Process Mining

- **Process Discovery**: is the process of extracting process models from raw event data.
- **Process Conformance**: this is the process of comparing existing process models with real business activity data to identify discrepancies, deviations or non-conformities between the planned process and the one actually executed.
- **Process Enhancement**: is the process of using information obtained through process mining to improve existing business processes.

Alpha Miner

Number of places of the Alpha Net: **3**

Number of transition of the Alpha Net: **55**



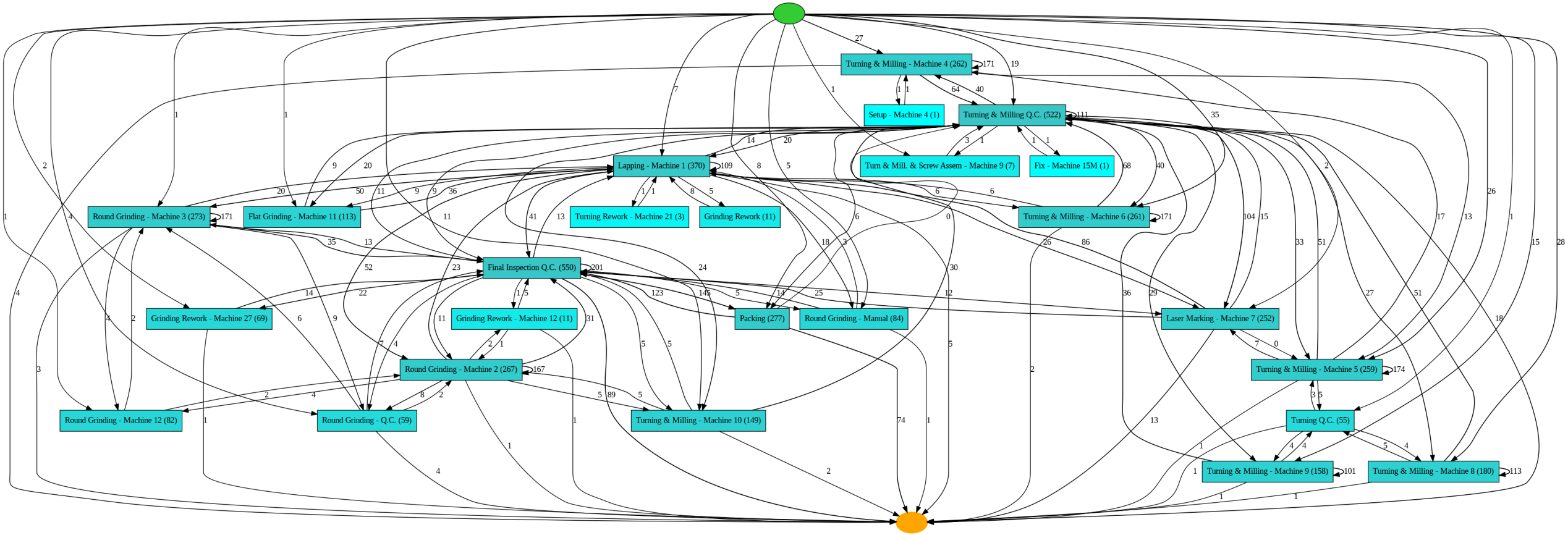
Alpha Miner

```
# Check soundness
woflan.apply(alpha_net, im_alpha, fm_alpha)
```

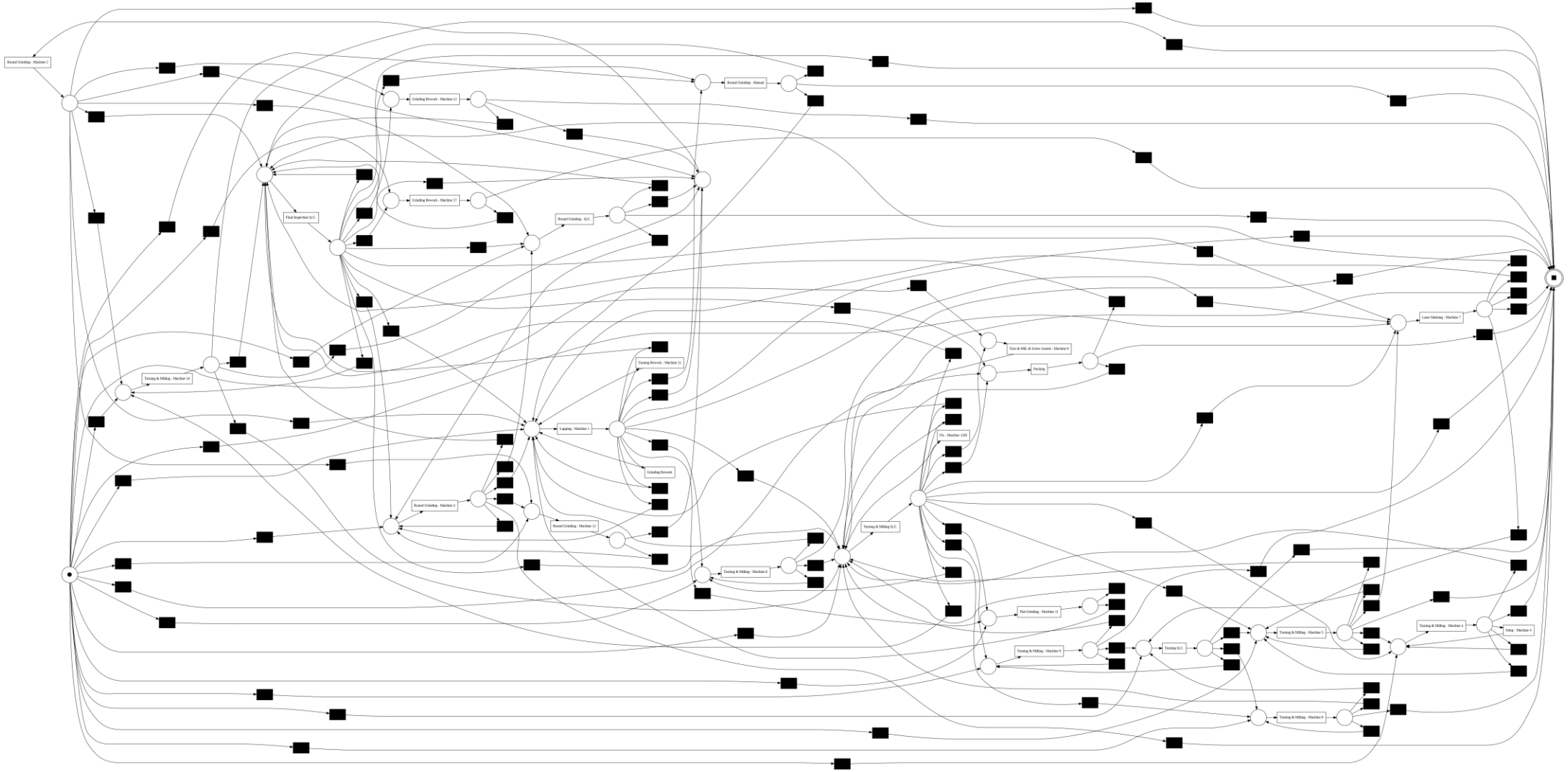
***Soundness**:*

- *Input is ok*.: This message indicates that the input provided to the algorithm, i.e. the Petri net and the start and end markings, are correct and valid for the analysis.
- *Petri Net is not a workflow net*.: This message indicates that the Petri Net is not a workflow net (a special class of Petri nets that respects certain properties, such as linearity and absence of output branches).
- *False*: Indicates that the Petri net may have problems such as deadlock, live-lock, or other error situations.

Heuristic Miner – Model



Heuristic Miner – Petri nets



Heuristic Miner – Petri nets

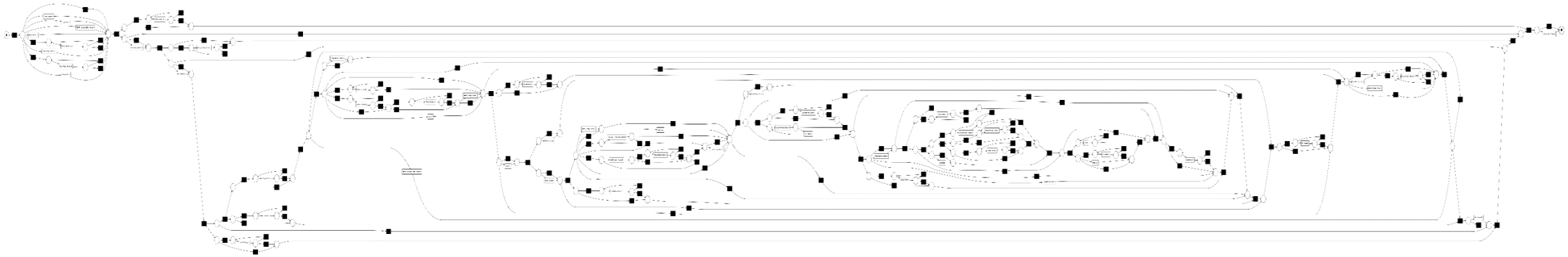
Number of places of the Heuristic Net: **43**

Number of transition of the Heuristic Net: **148**

Soundness:

- *Input is ok.*
- *Petri Net is a workflow net.*
- *Every place is covered by s-components.*
- *There are no dead tasks.*
- *All tasks are live.*
- *True*

Inductive Miner



Number of places of the Inductive Net: **136**

Number of transition of the Inductive Net: **220**

***Soundness*:**

- *Input is ok.*
- *Petri Net is a workflow net.*
- *Every place is covered by s-components.*
- *There are no dead tasks.*
- *All tasks are live.*
- *True*

Results

Evaluating the different petrines:

		Alpha net	Heuristic net	Inductive net
Fitness token based replay	**Percentage fit traces**	2,67%	24%	99,56%
	Average trace fitness	22,1%	90,8%	99,98%
	Log fitness	11%	92,2%	99,98%
	Percentage of fitting traces	2,67%	24%	99,56%
Fitness alignments	**Percentage fit traces**	2,67%	21,33%	21,33%
	Average fitness	23,33%	80,1%	80,04%
	Percentage of fitting traces	13,34%	21,33%	21,33%
	Average trace fitness	2,67%	80,1%	80,04%
	Log fitness	78,9%	78,9%	78,91%
	Precision token based replay	39,79%	36,7%	8,31%
	Precision alignments	39,79%	42,8%	42,83%
	Generalization	58,2%	65,6%	69,76%

Conclusion

Fitness and Precision:

- Alpha Petri net: Has the lowest degree of fitness and accuracy, indicating that the model may not adequately fit the event log.
- Heuristic Petri net: Shows good performance in both fitness and accuracy, suggesting a good fit between the model and the event log.
- Inductive Petri net: Achieves the highest degree of fitness, but lowest accuracy, indicating possible overfitting of the model.

Generalization:

- Alpha Petri net has the lowest generalization, which may indicate that the model is unable to effectively adapt to new data.
- Heuristic Petri net and Inductive Pet show better generalization, which suggests that they are more adaptable and could work well even with previously unseen data.

Techniques: the results were evaluated using two different techniques: token-based replay and alignment. It is important to note how performance can vary depending on the technique used.

Model Complexity: the Inductive Pet model appears to be the most complex, with better fitness results, but lower accuracy. This may indicate that the model is better able to capture the complexity of the data, but may be more prone to overfitting.

Thanks for listening

Reference:

Dataset:

https://data.4tu.nl/articles/_/12697997/1