Process Mining: Data Science in Action

Aligning Observed and Modeled Behavior

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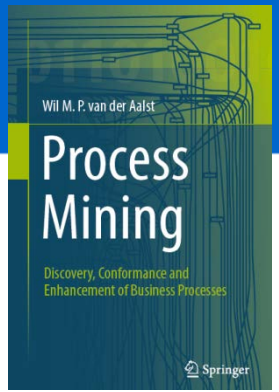
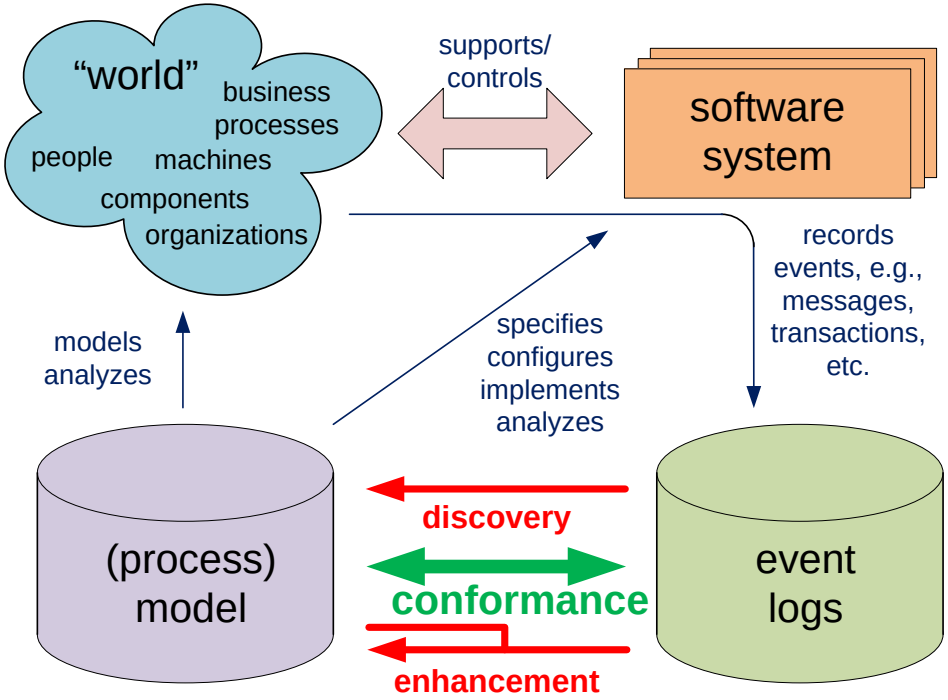
www.processmining.org



Technische Universiteit Eindhoven University of Technology

Where innovation starts

Conformance checking



1. Conformance checking using causal footprints.
2. Conformance checking based on token-based replay.
3. **Alignment-based conformance checking.**

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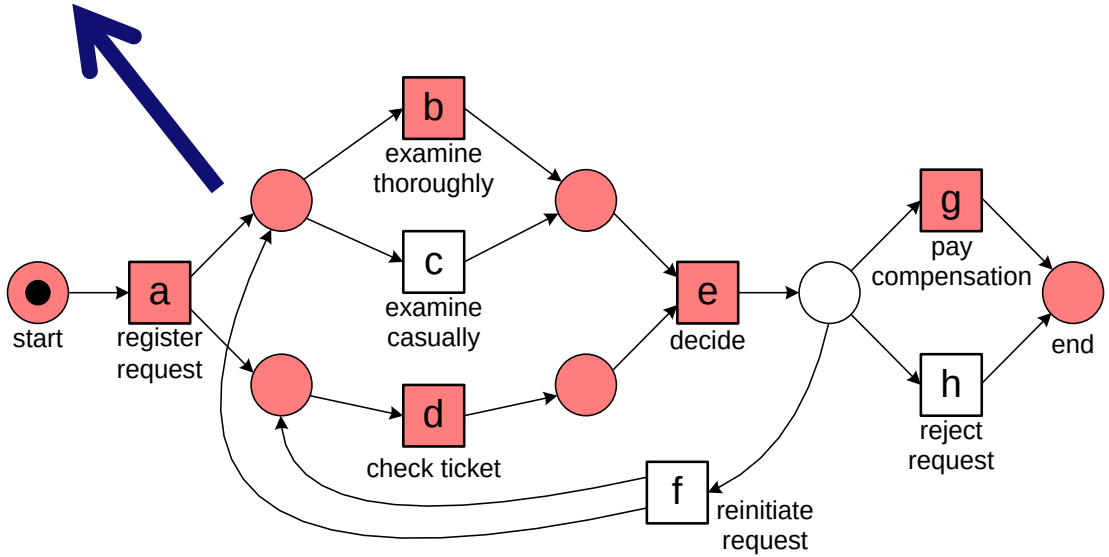
Requirements

- Conformance checking should not impose restrictions on the process notation (e.g., silent transitions and two transitions with the same label should be possible).
- Should provide a "closest matching path" through the process model for any trace in the event log.
  - Also required for performance analysis!
  - Beyond the analysis of replay fitness (advanced diagnostics, precision, generalization, etc.).

Alignments

a	b	d	e	g
a	b	d	e	g

⟨a,b,d,e,g⟩

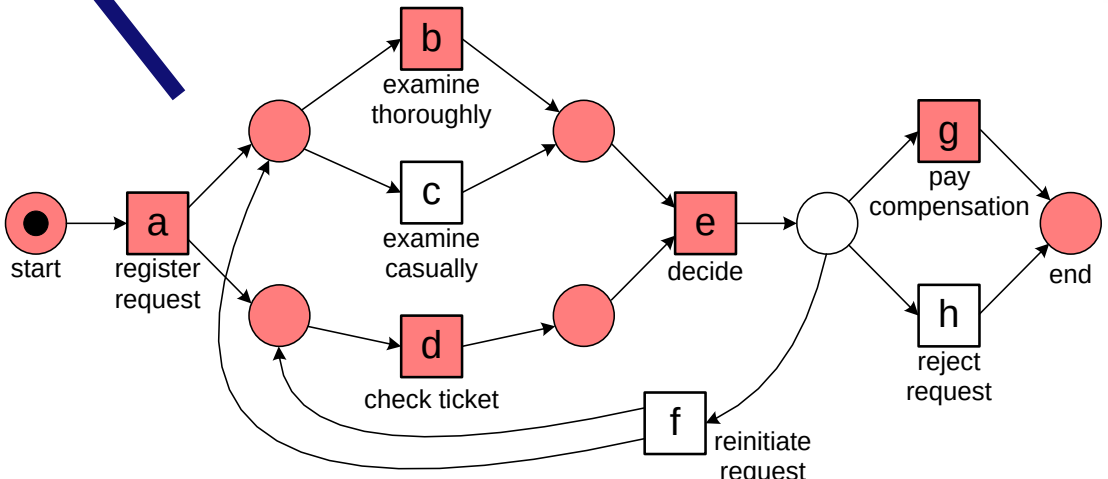


#	trace
455	acdeh
191	abdeg
177	adceh
144	abdeh
111	acdeg
82	adceg
56	adbeh
47	acdefdbeh
38	adbeg
33	acdefbdeh
14	acdefbdeg
11	acdefdbeg
9	adcefcdeh
8	adcefdbeh
5	adcefbdeg
3	acdefbdefdbeg
2	adcefdbeg
2	adcefbdefbdeg
1	adcefdbefbdeh
1	adbefbdefdbeg
1	adcefdbefcdefdbeg
1391	

Alignments

a	»	d	e	g	h
a	b	d	e	g	»

⟨a,d,e,g,h⟩



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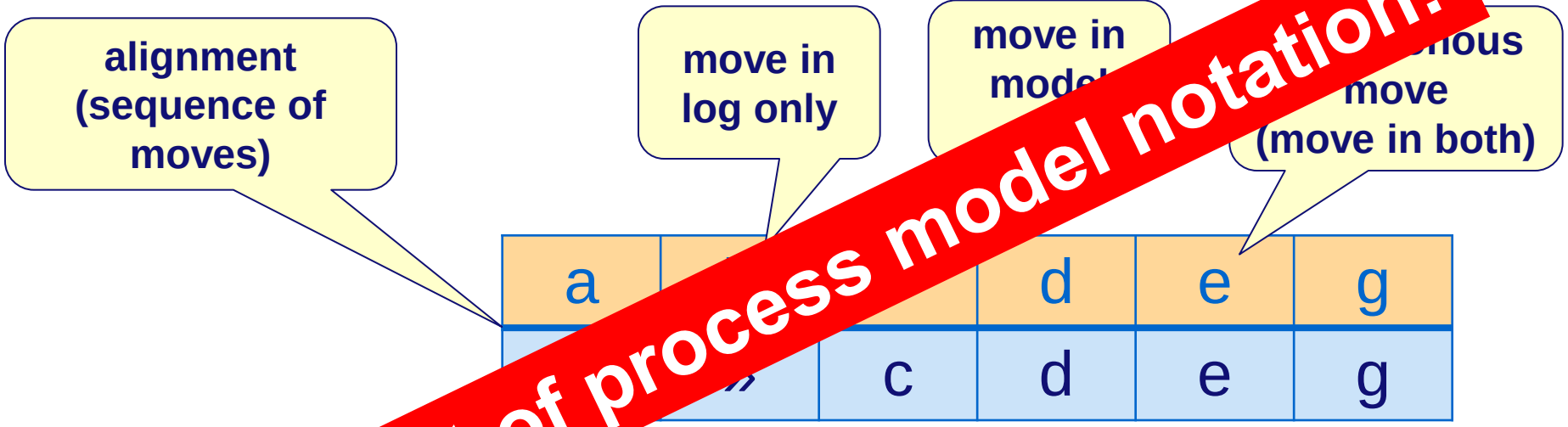
Terminology



Independent of process model notation!

- Projecti… row (remove "no moves") corresponds to t… in the event log.
  …tion on bottom row (remove "no moves") …rresponds to a run of the model.

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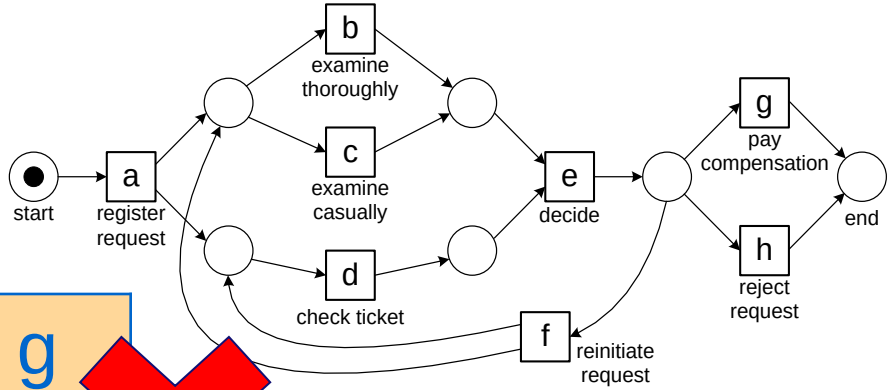
Optimal alignment for ⟨a,b,d,e,g⟩

a	b	d	e	g
a	b	d	e	g



a	b	»	d	e	g
a	»	c	d	e	g

a	b	d	e	g	»	»	»	»	»
»	»	»	»	»	a	c	d	e	g

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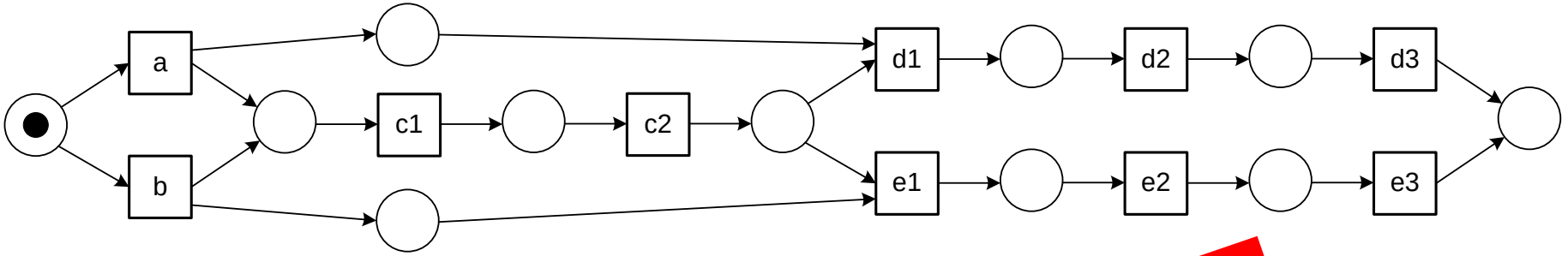
Optimal alignment for ⟨a,c1,c2,e1,e2,e3⟩ ?



a	»	c1	c2	e1	e2	e3
»	b	c1	c2	e1		

a	c1			»	e1	e2	e3
a	c	d1	d2	d3	»	»	»

Depends on cost function!

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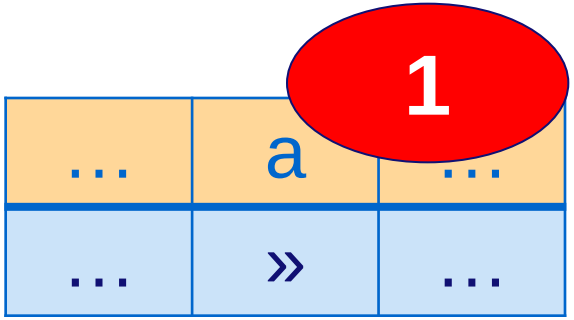
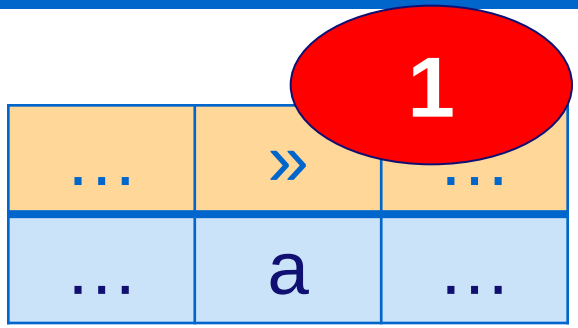
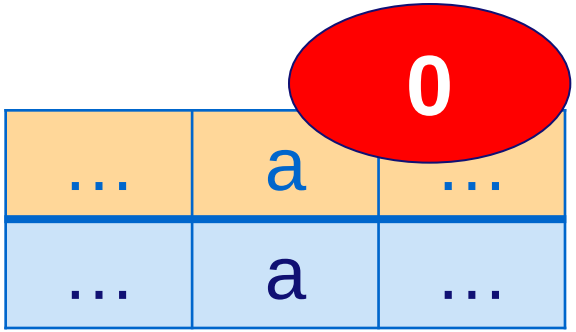
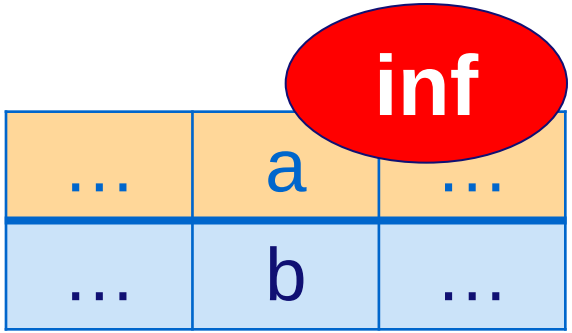
Standard cost function
count »'s in alignment









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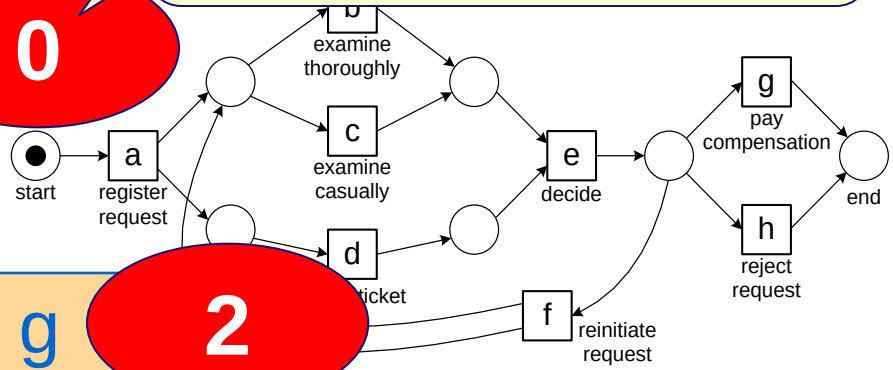
Using the standard cost f

optimal
there is no other alignment that has lower costs

a	b	d	e	g
a	b	d	e	g

0



a	b	»	d	e	g
a	»	c	d	e	g

2

a	b	d	e	g	»	»	»	»	»
»	»	»	»	»	a	c	d	e	g

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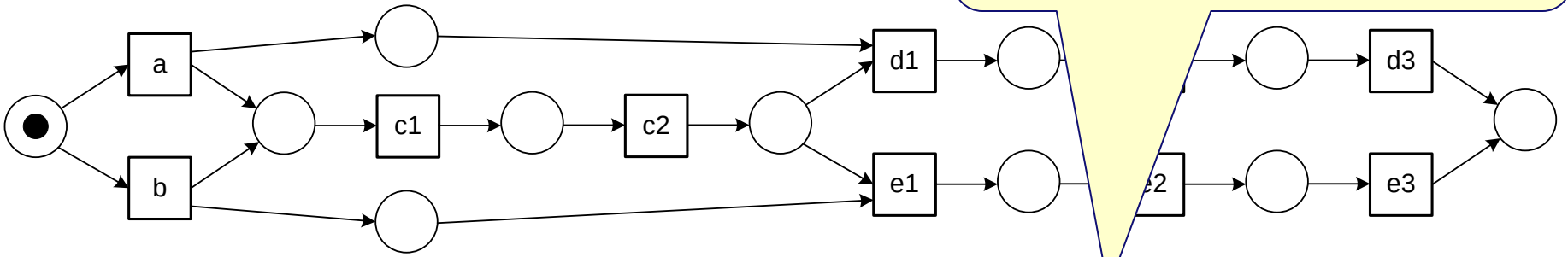
Using the standard cost fu

trace in log: ⟨a,c1,c2,e1,e2,e3⟩

optimal
there is no other alignment that has lower costs



a	»	c1	c2	e1	e2	e3
»	b	c1	c2	e1	e2	e3

2

a	c1	c2	»	»	»	e1	e2	e3
a	c1	c2	d1	d2	d3	»	»	»

6

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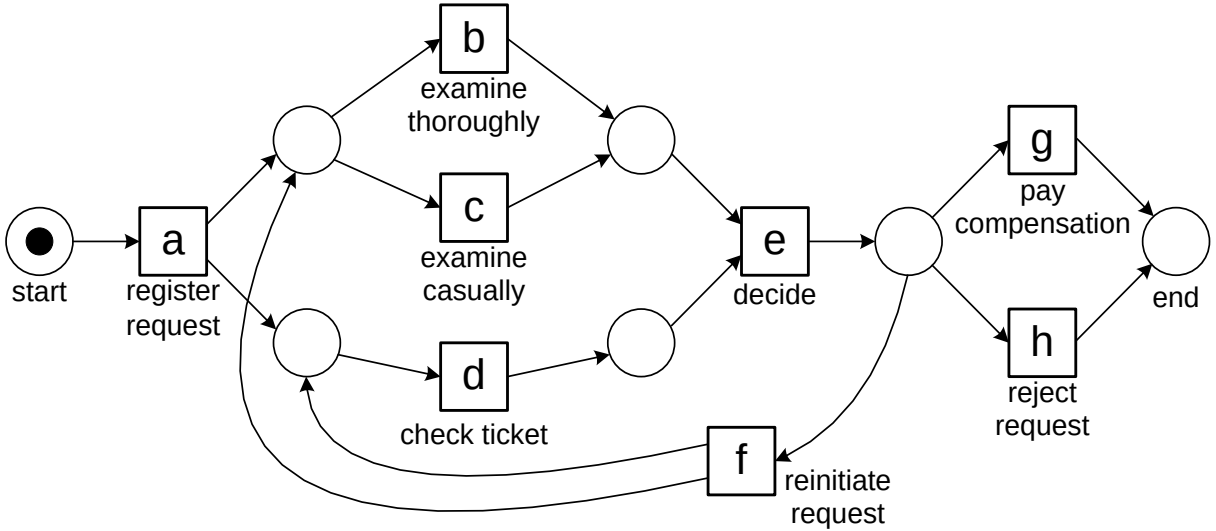
Optimal alignment for ⟨a,b,e,f,d,e,g⟩ (1/2)

a	b	e	f	d	e	g
a	b	»	»	d	e	g

2



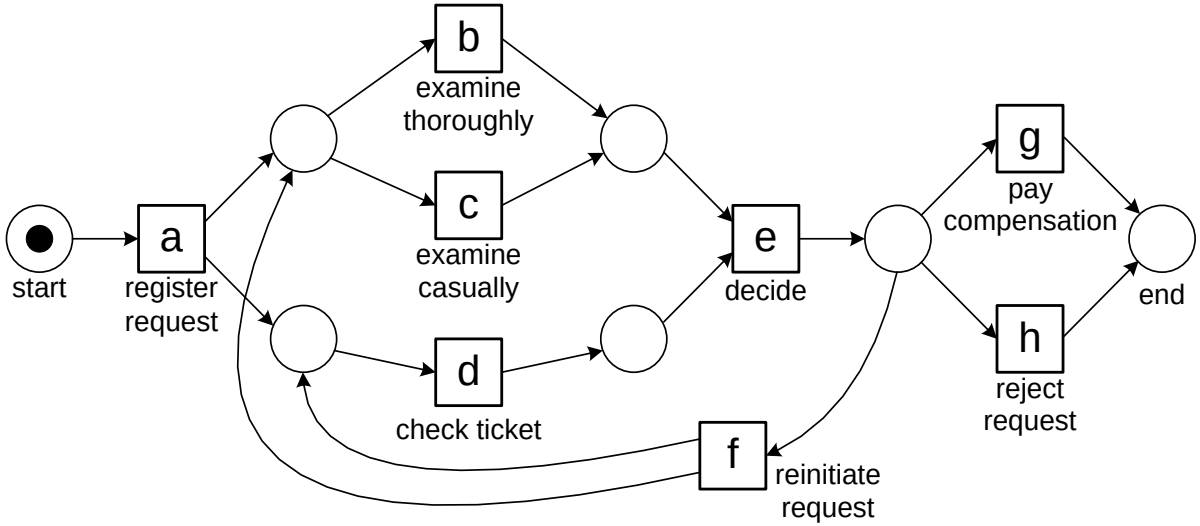
loop is not taken: e and f in event log are discarded

TU/e

Optimal alignment for ⟨a,b,e,f,d,e,g⟩ (2/2)

a	b	»	e	f	d	»	e	g
a	b	d	e	f	d	b	e	g

2



loop is taken: d and b are missing in event log

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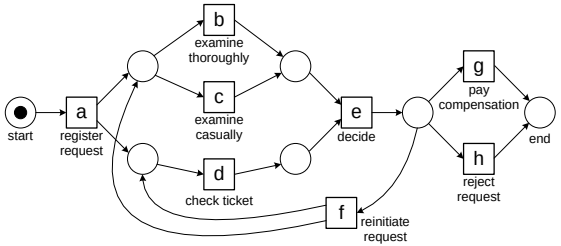
Not one unique optimal alignment

a	b	»	e	f	d	»	e	g
a	b	d	e	f	d	b	e	g

2

a	b	e	f	d	e	g
a	b	»	»	d	e	g

2



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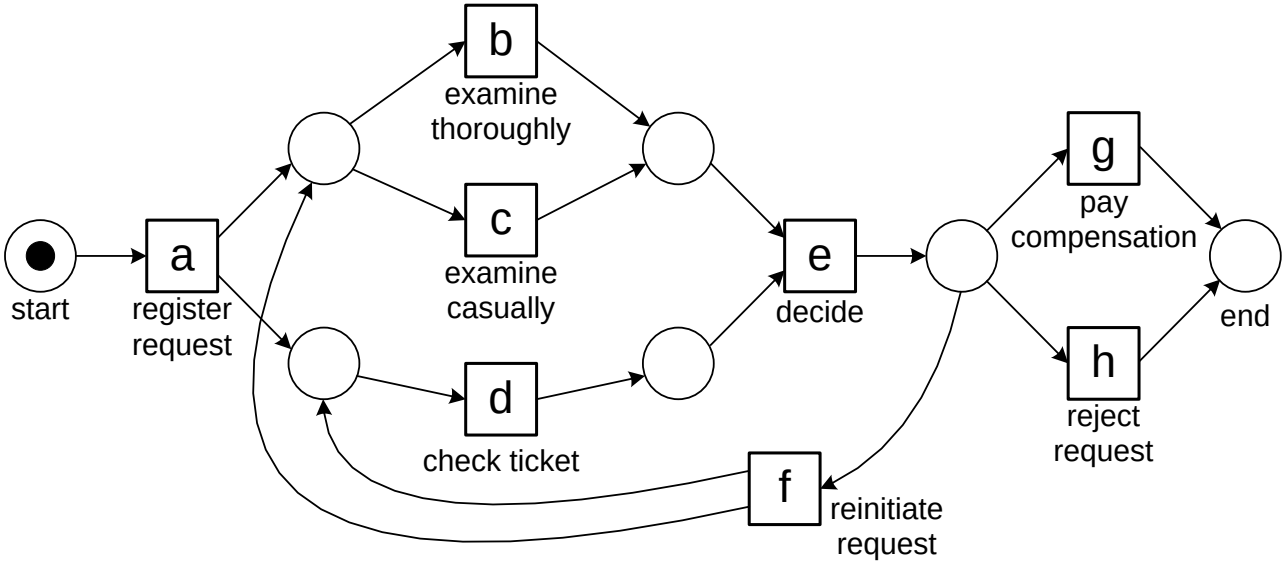
Question: How many optimal alignments are there for ⟨a,b,e,f,d,e,g⟩ ?



⟨a,b,e,f,d,e,g⟩

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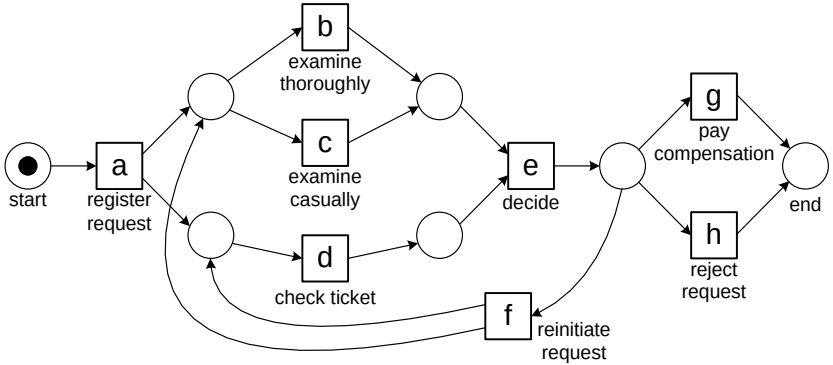
Answer: 9

1+(2x2)+(2x2)=9 optimal alignments having cost 2

a	b	e	f	d	e	g
a	b	»	»	d	e	g

1x



move in model can be reordered in concurrent part

4x

a	b	»	e	f	d	»	e	g
a	b	d	e	f	d	b	e	g

4x

a	b	»	e	f	d	»	e	g
a	b	d	e	f	d	c	e	g

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Any cost structure is possible

...	send-letter(John,4 weeks, $400)	...
...	send-email(Sue,3 weeks,$500)	...

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Any cost structure is possible

...	send-letter(John,4 weeks, $400)	...
...	send-email(Sue,3 weeks,$500)	...

similar activities (lower costs for related activities)

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Any cost structure is possible

...	send-letter(John,4 weeks, $400)	...
...	send-email(Sue,3 weeks,$50	...

resource-related conformance costs (done by someone that does or does not have the specified role)

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Any cost structure is possible

...	send-letter(John,4 weeks, $400)	...
...	send-email(Sue,3 weeks,$500)	...

time-related conformance costs (activity should happen within a preset deadline)

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Any cost structure is possible

...	send-letter(John,4 weeks, $400)	...
...	send-email(Sue,3 weeks,$500)	...

data-related conformance costs (routing condition is violated, e.g., path only for more valuable orders)

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Any cost structure is possible

...	send-letter(John,4 weeks, $400)	...
...	send-email(Sue,3 weeks,$500)	...

risk-related conformance costs, context-dependent conformance costs, …

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Computing fitness

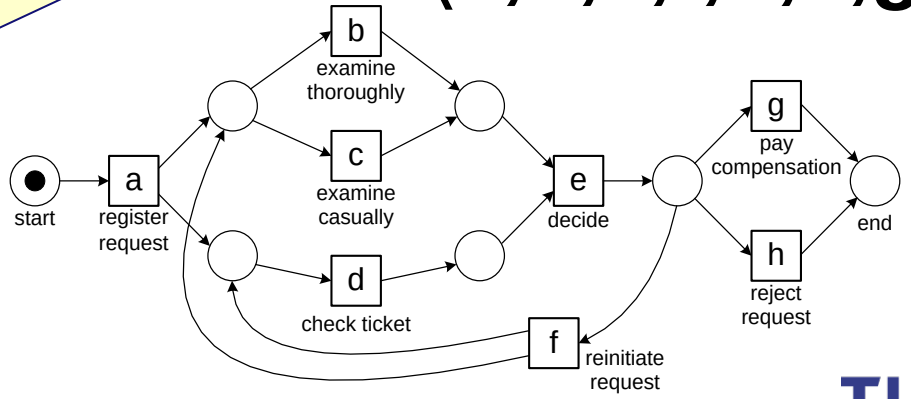
C… …n optimal alignment with a mo… …model.

all events cause a move in log only

shortest path from initial state to final state

$$1 - \frac{2}{7+5} = 0.833$$

⟨a,b,e,f,d,e,g⟩



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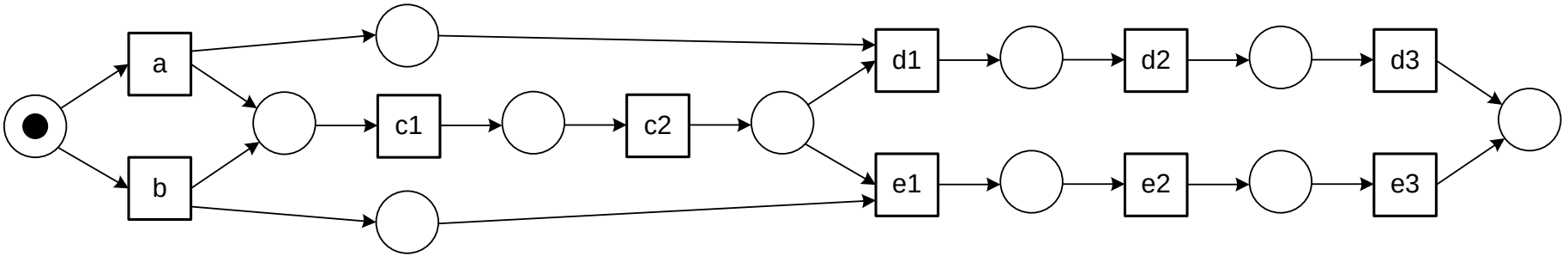
Question: Compute alignment-based fitness

$$\langle a, c1, c2, e1, e2, e3 \rangle$$



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Answer

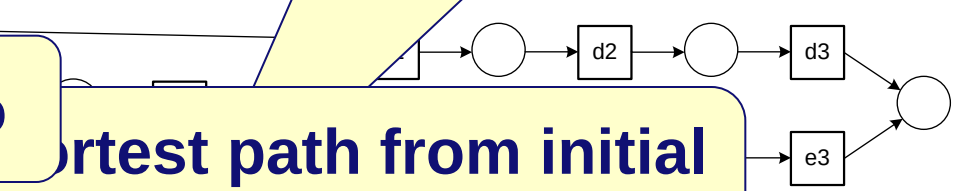
cost of optimal alignment = 2

⟨a,c1,c2,e1,e2,e3⟩

all ev… move in log only

worst-case scenario

…ortest path from initial state to final state



a		c1	c2		e2	
»		c1	c2	e	e2	e

a	c1	c2	e1	e2	e3	»	»	»	»	»	»
»	»	»	»	»	»	a	c1	c2	d1	d2	d3

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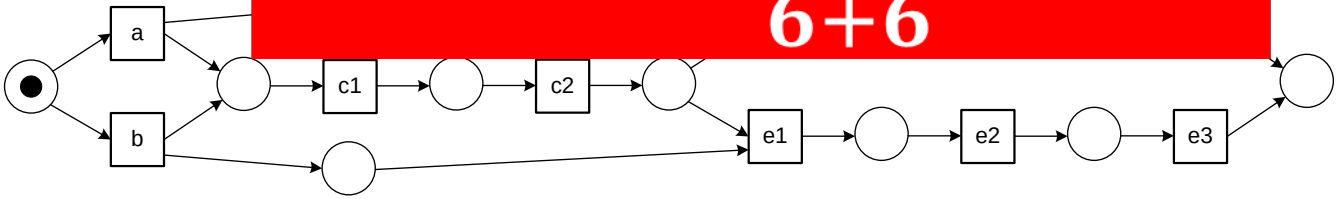
Answer

$$\text{fitness} = 1 - \frac{2}{6+6} = 0.833$$

⟨a,c1,c2,e1,e2,e3⟩



2

a	»	c1	c2	e1	e2	e3
»	b	c1	c2	e1	e2	e3

6

a	c1	c2	e1	e2	e3	»	»	»	»	»	»
»	»	»	»	»	»	a	c1	c2	d1	d2	d3

6

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Advantages of aligning log and model

- Observed behavior is directly related to modeled behavior.
- Very flexible (any cost structure).
- Detailed diagnostics.
- After aligning log and model, other quality dimensions can be investigated (separation of concerns).

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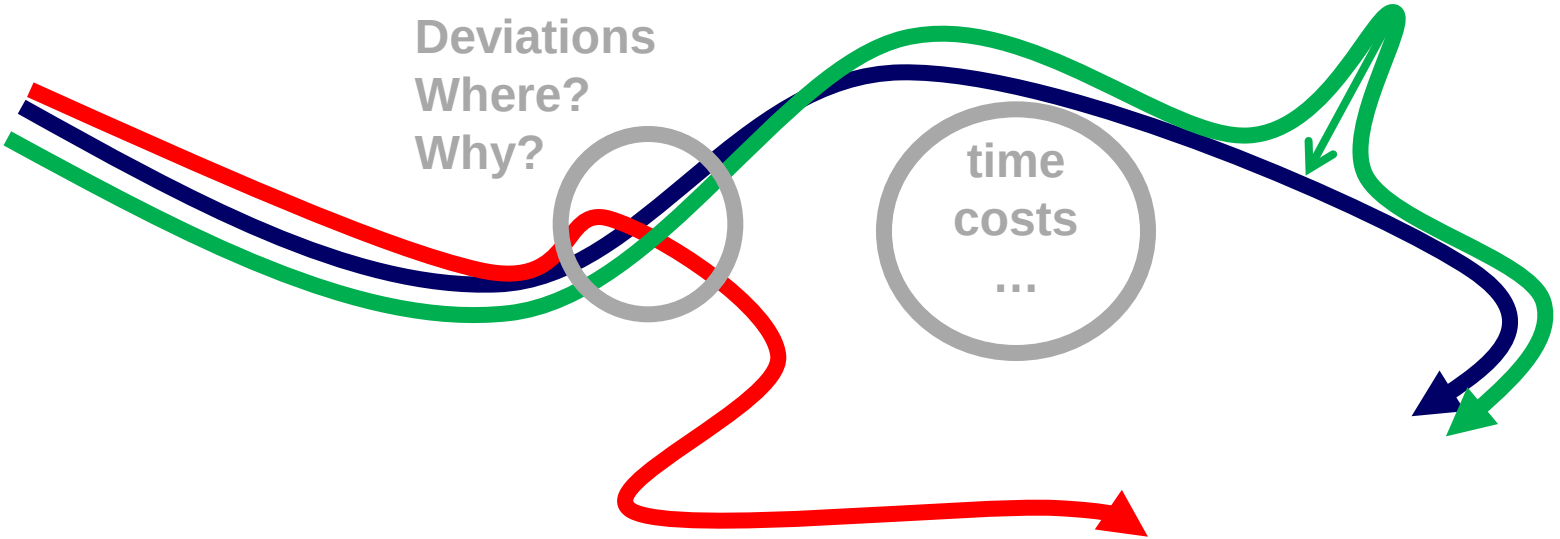
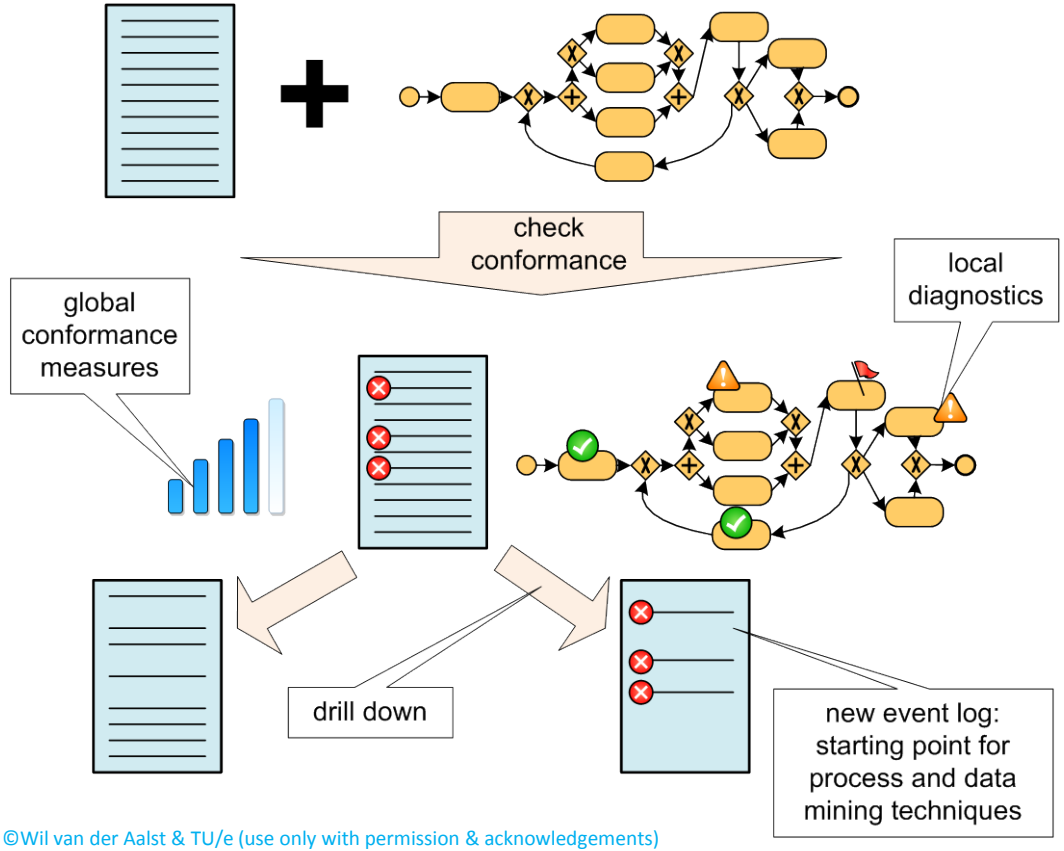

Deviations
Where?
Why?
time
costs
...

Drilling down



- Create event log containing deviating (or non-deviating) cases.
- Apply process mining to new log.
- Comparative process mining.

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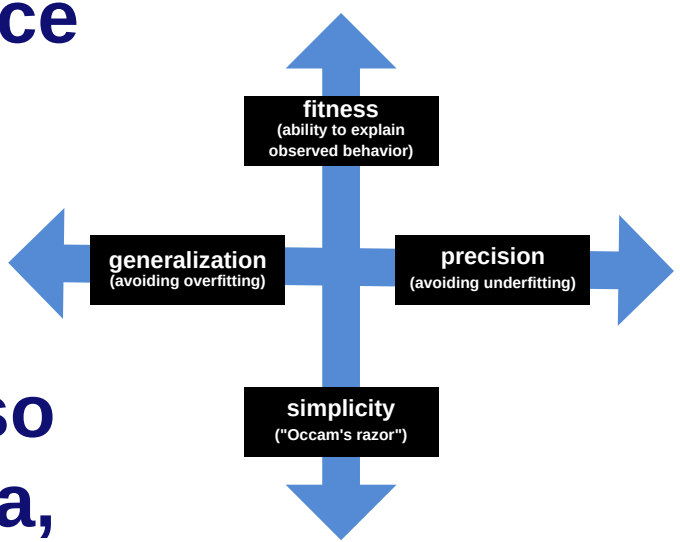
Beyond fitness and control-flow

- There are also solid conformance measures for precision, generalization, and simplicity.
- Multiple definitions possible.
- Conformance checking may also include other perspectives (data, resources, time, cost, etc.).
- Example: data-aware alignments.



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Part I: Preliminaries

- Chapter 1: Introduction
- Chapter 2: Process Modeling and Analysis
- Chapter 3: Data Mining

Part II: From Event Logs to Process Models

- Chapter 4: Getting the Data
- Chapter 5: Process Discovery: An Introduction
- Chapter 6: Advanced Process Discovery Techniques

Part III: Beyond Process Discovery

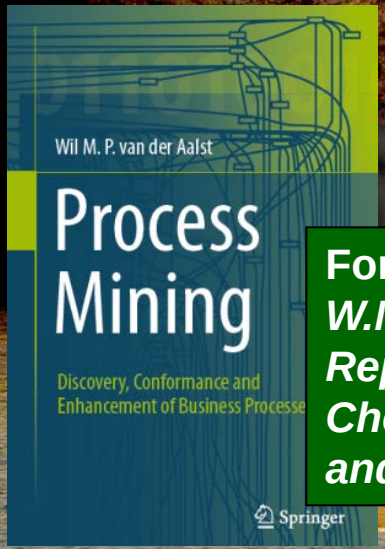
- Chapter 7: Conformance Checking
- Chapter 8: Mining Additional Perspectives
- Chapter 9: Operational Support

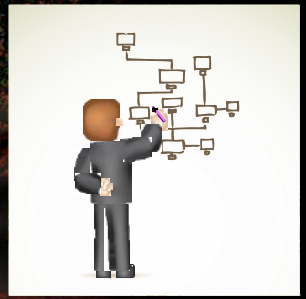
Part IV: Putting Process Mining to Work

- Chapter 10: Tool Support
- Chapter 11: Analyzing "Lasagna Processes"
- Chapter 12: Analyzing "Spaghetti Processes"

Part V: Reflection

- Chapter 13: Cartography and Navigation
- Chapter 14: Epilogue





For more details see:
W.M.P. van der Aalst, A. Adriansyah, and B. van Dongen. Replaying History on Process Models for Conformance Checking and Performance Analysis. WIREs Data Mining and Knowledge Discovery, 2(2):182-192, 2012.

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