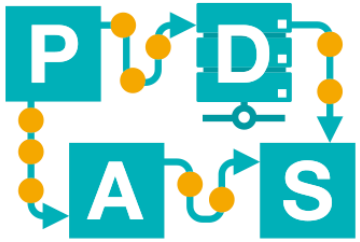
Heuristic Miner and Region-Based Mining

Nina Graves

BPI-Instruction 5



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Heuristic Mining

Causal Net
Question 1

Consider the C-net in the figure on the right to work on the following tasks and questions.

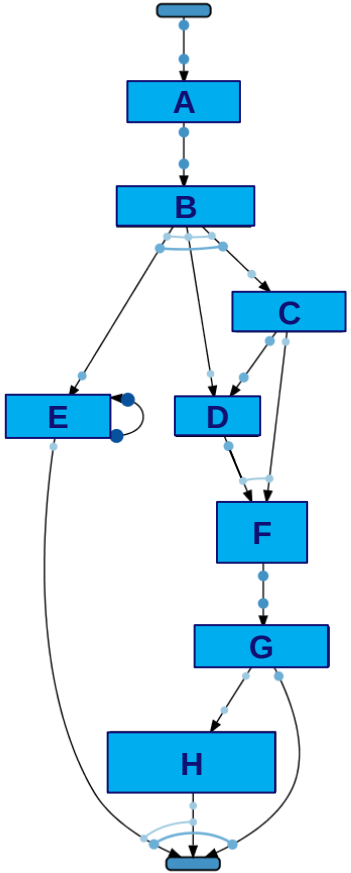
a) Provide a valid binding sequence for the following trace:

$$\sigma = \langle start, A, B, C, D, F, E, E, G, end \rangle$$

b) Is it possible to construct a valid binding sequence using the following binding:

$$(activity, inputB, outputB\ ) = (B, \{A\}, \{E, C\})$$

Explain your answer.



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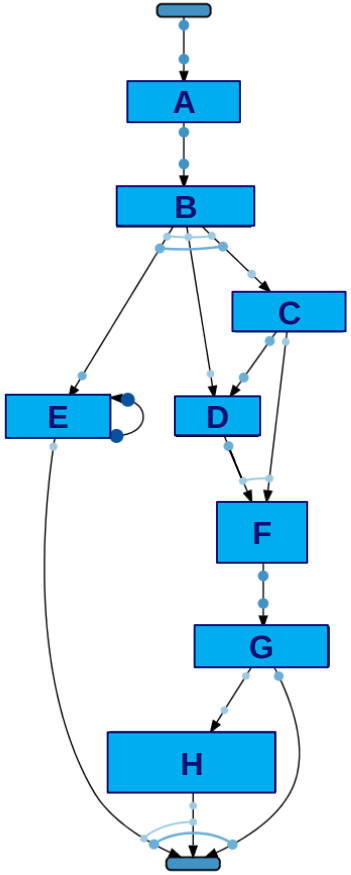
Causal Net

Solution Q1 a)

$\sigma = \langle start, A, B, C, D, F, E, E, G, end \rangle$

Input Binding	Activity	Output Binding	State / Pending Obl.
$\emptyset$	$start$	$\{A\}$	$\{(start, A)\}$
$\{start\}$	A	$\{B\}$	$\{(A, B)\}$
$\{A\}$	B	$\{E, D, C\}$	$\{(B, E), (B, D), (B, C)\}$
$\{B\}$	C	$\{F\}$	$\{(B, E), (B, D), (C, F)\}$
$\{B\}$	D	$\{F\}$	$\{(B, E), (D, F), (C, F)\}$
$\{C, D\}$	F	$\{G\}$	$\{(B, E), (F, G)\}$
$\{B\}$	E	$\{E\}$	$\{(E, E), (F, G)\}$
$\{E\}$	E	$\{end\}$	$\{(E, end), (F, G)\}$
$\{F\}$	G	$\{end\}$	$\{(E, end), (G, end)\}$
$\{E, G\}$	end	$\emptyset$	$\emptyset$



Causal Net

Solution Q1 a)

$\sigma = \langle start, A, B, C, D, F, E, E, G, end \rangle$

Resulting in the following binding sequence:

$$\left\langle \begin{array}{c} (start, \emptyset, \{A\}), (A, \{start\}, \{B\}), (B, \{A\}, \{E, D, C\}), (C, \{B\}, \{F\}), \\ (D, \{B\}, \{F\}), (F, \{C, D\}, \{G\}), (E, \{B\}, \{E\}), (E, \{E\}, \{end\}), \\ (G, \{F\}, \{end\}), (end, \{E, G\}, \emptyset) \end{array} \right\rangle$$

Valid?

- Begins with *start* ✓
- Ends with *end* ✓
- All other bindings refer to an *activity in A* which is *neither the start nor the end* ✓
- *No pending obligations (last colomn)* at the end ✓
- At any point in the sequence only pending obligations were fulfilled. ✓

YES!

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Causal Net

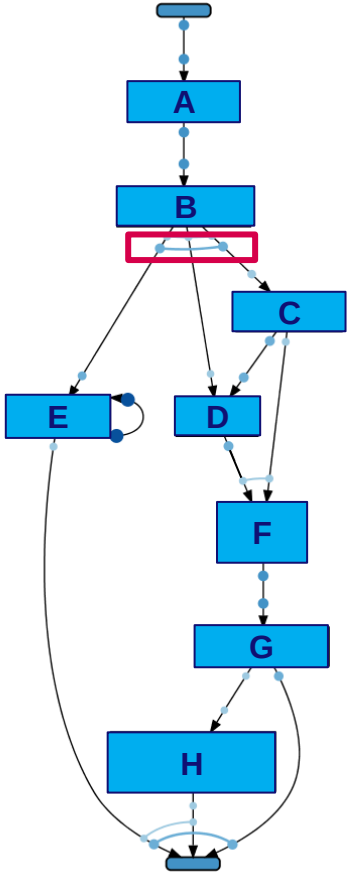
Solution Q1 b)

b) Is it possible to construct a valid binding sequence using the following binding:

$$(activity, inputB, outputB) = (B, \{A\}, \{E, C\})$$

Explain your answer.

1. Any valid sequence requires activity *F*.
2. *F* only has one input binding, containing both *D* and *C*.
3. As *D* is not part of the given output binding of *B*, *D* has to be enabled by *C*.
4. But *C* can only enable either *D* or F, not both.
5. No valid binding sequence can contain the output binding *{E,C}* for activity *B*.



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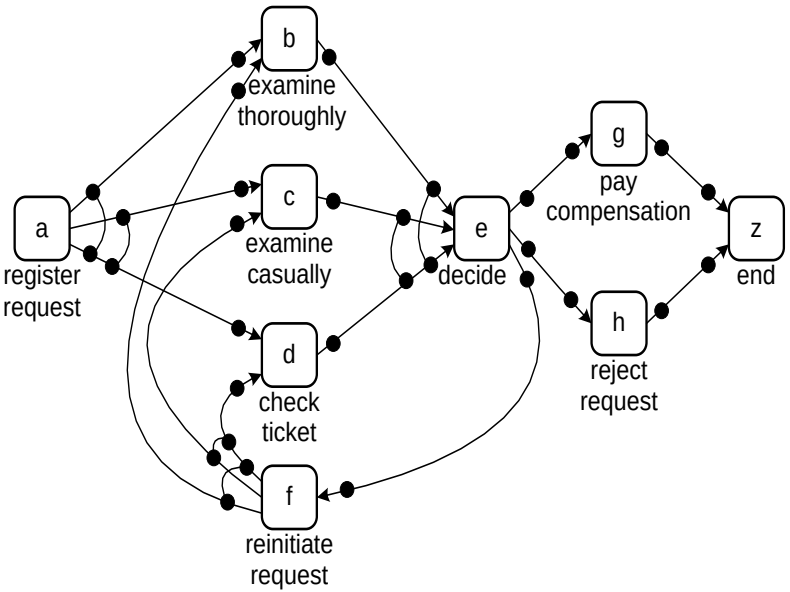
Causal Net
Question 2

Consider the C-net in the figure on the right and answer the following questions:

a) Does the C-net accept any activity sequence including both *g* and *h*?

b) Does the C-net accept any activity sequence where activity *e* occurs without *d* occurring first? If yes, give an example; if no, explain why not.

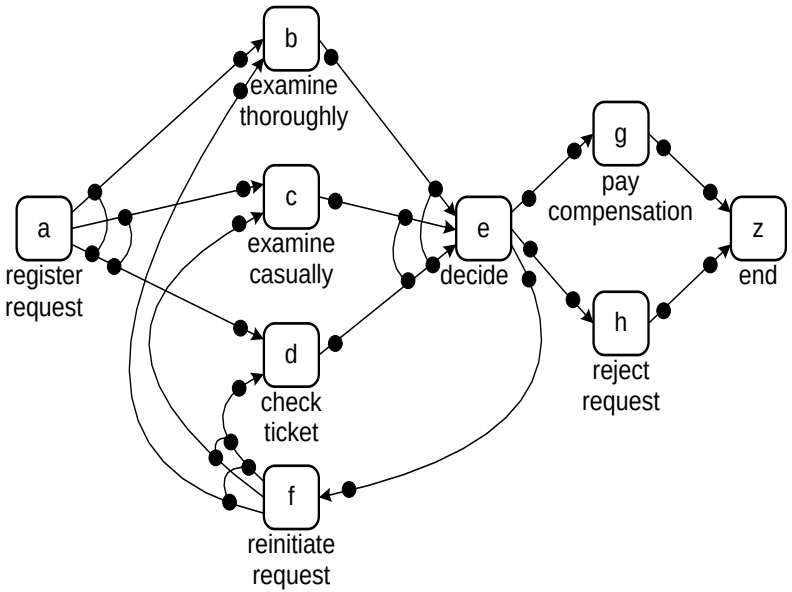
c) Give an activity sequence including activity *f* that is accepted by this C-net and starts with the occurrence of *a* with output binding {*c*,*d*}.



Causal Net
Solution Q2 a)

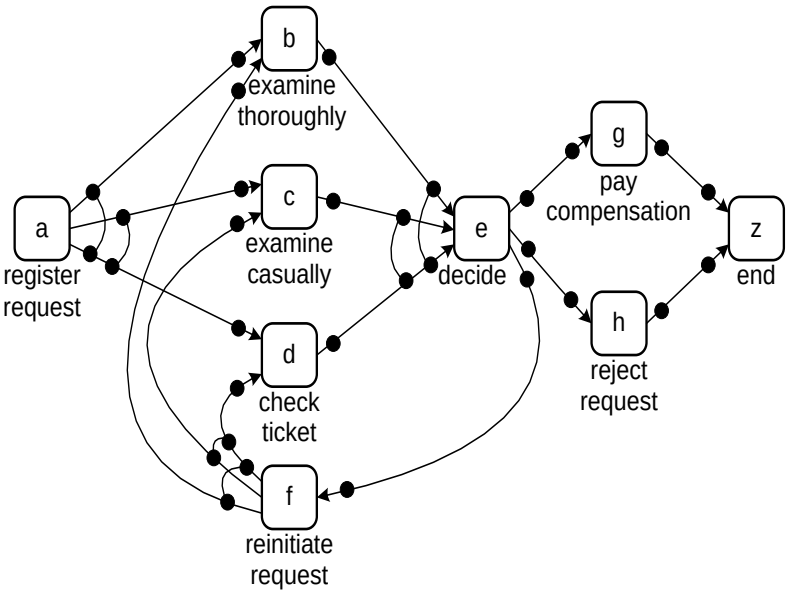
a) Does the C-net accept any activity sequence including both *g* and *h*?

There is no sequence including both *g* and *h*, because the choice between them is exclusive (and there is no loop to go back afterwards).



Causal Net
Solution Q2 b)

b) Does the C-net accept any activity sequence where *e* occurs without *d* occurring first? If yes, give an example; if no, explain why not.



Activity *e* *is* possible only if proceeded by either (*b* and *d)* or (*c* and *d)* before. Therefore, there will always be an occurrence of *d* before *e*.

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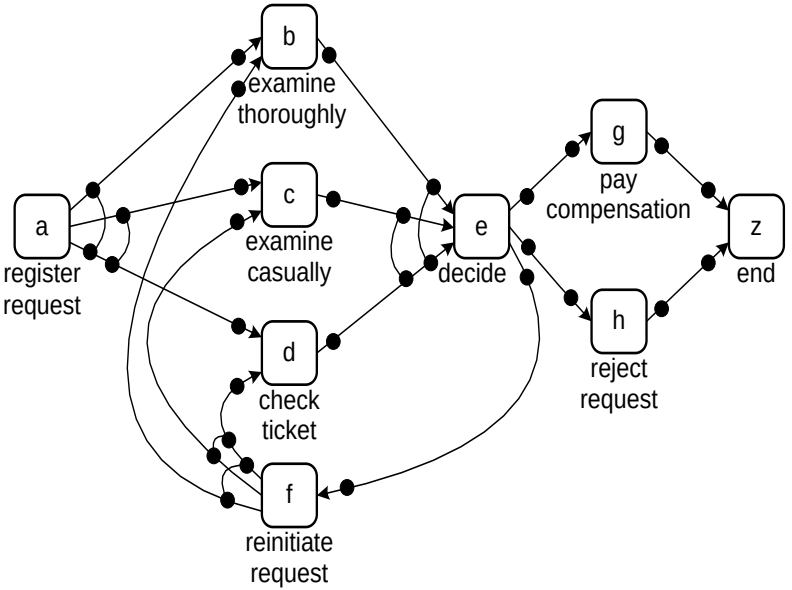
Causal Net
Solution Q2 c)

c) Give an activity sequence including activity *f* that is accepted by this C-net and starts with the occurrence of *a* with output binding {*c*,*d*}.

A possible example is $\langle a, c, d, e, f, d, c, e, g, z \rangle$.



Heuristic Miner

Question 3

$$L_1 = [\langle a, b, e \rangle^{10}, \langle a, c, e \rangle^{12}, \langle d, b, f \rangle^{8}, \langle d, c, f \rangle^{15}]$$

a) Compute the dependency measures matrix.

b) Construct the dependency graph with the following thresholds: At least 10 direct successions and a dependency of at least 0.9.

c) Construct the C-net based on the dependency graph. Use a window size of 2.

d) Give an activity sequence that is possible in the C-net, but is not included in the event log.

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Heuristic Miner

Question 3

$$L_1 = [\langle a, b, e \rangle^{10}, \langle a, c, e \rangle^{12}, \langle d, b, f \rangle^{8}, \langle d, c, f \rangle^{15}]$$

→ $[\langle \boldsymbol{S}, a, b, e, \boldsymbol{E} \rangle^{10}, \langle \boldsymbol{S}, a, c, e, \boldsymbol{E} \rangle^{12}, \langle \boldsymbol{S}, d, b, f, \boldsymbol{E} \rangle^{8}, \langle \boldsymbol{S}, d, c, f, \boldsymbol{E} \rangle^{15}]$

Non-unique starting and ending activities → add artificial start and end.

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Solution Q3 a)

$$L_1 = [\langle \boldsymbol{S}, a, b, e, \boldsymbol{E} \rangle^{10}, \langle \boldsymbol{S}, a, c, e, \boldsymbol{E} \rangle^{12}, \langle \boldsymbol{S}, d, b, f, \boldsymbol{E} \rangle^{8}, \langle \boldsymbol{S}, d, c, f, \boldsymbol{E} \rangle^{15}]$$

a) Compute the dependency measures matrix.

Step 1: Count direct successions

$\|>_L\|$	S	a	b	c	d	e	f	E
S	0	**22**	0	0	**23**	0	0	0
a	0	0	**10**	**12**	0	0	0	0
b	0	0	0	0	0	**10**	**8**	0
c	0	0	0	0	0	**12**	**15**	0
d	0	0	**8**	**15**	0	0	0	0
e	0	0	0	0	0	0	0	**22**
f	0	0	0	0	0	0	0	**23**
E	0	0	0	0	0	0	0	0

Step 2: Calculate dependencies

$$|\boldsymbol{a} \Rightarrow_L \boldsymbol{b}| = \begin{cases} \dfrac{|\boldsymbol{a} >_L \boldsymbol{b}| - |\boldsymbol{b} >_L \boldsymbol{a}|}{|\boldsymbol{a} >_L \boldsymbol{b}| + |\boldsymbol{b} >_L \boldsymbol{a}| + \boldsymbol{1}} & \boldsymbol{if\ a \neq b} \\ \dfrac{|\boldsymbol{a} >_L \boldsymbol{a}|}{|\boldsymbol{a} >_L \boldsymbol{a}| + \boldsymbol{1}} & \boldsymbol{if\ a = b} \end{cases}$$

Negative dependencies are discarded.

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Heuristic Miner

Solution Q3 a)

$$L_1 = [\langle \boldsymbol{S}, a, b, e, \boldsymbol{E} \rangle^{10}, \langle \boldsymbol{S}, a, c, e, \boldsymbol{E} \rangle^{12}, \langle \boldsymbol{S}, d, b, f, \boldsymbol{E} \rangle^{8}, \langle \boldsymbol{S}, d, c, f, \boldsymbol{E} \rangle^{15}]$$

a) Compute the dependency measures matrix.

Step 1: Count direct successions

$\lvert >_L \rvert$	S	a	b	c	d	e	f	E
S	0	**22**	0	0	**23**	0	0	0
a	0	0	**10**	**12**	0	0	0	0
b	0	0	0	0	0	**10**	**8**	0
c	0	0	0	0	0	**12**	**15**	0
d	0	0	**8**	**15**	0	0	0	0
e	0	0	0	0	0	0	0	**22**
f	0	0	0	0	0	0	0	**23**
E	0	0	0	0	0	0	0	0

Step 2: Calculate dependencies

$\lvert \Rightarrow_L \rvert$	S	a	b	c	d	e	f	E
S	0	**0.96**	0	0	**0.96**	0	0	0
a	0	0	**0.91**	**0.92**	0	0	0	0
b	0	0	0	0	0	**0.91**	**0.89**	0
c	0	0	0	0	0	**0.92**	**0.94**	0
d	0	0	**0.89**	**0.94**	0	0	0	0
e	0	0	0	0	0	0	0	**0.96**
f	0	0	0	0	0	0	0	**0.96**
E	0	0	0	0	0	0	0	0

Heuristic Miner

Solution Q3 b)

$$L_1 = [\langle \boldsymbol{S}, a, b, e, \boldsymbol{E} \rangle^{10}, \langle \boldsymbol{S}, a, c, e, \boldsymbol{E} \rangle^{12}, \langle \boldsymbol{S}, d, b, f, \boldsymbol{E} \rangle^{8}, \langle \boldsymbol{S}, d, c, f, \boldsymbol{E} \rangle^{15}]$$

b) Construct the dependency graph with the follwoing thresholds:
At least **10** direct successions and a dependency of at least **0.9.**

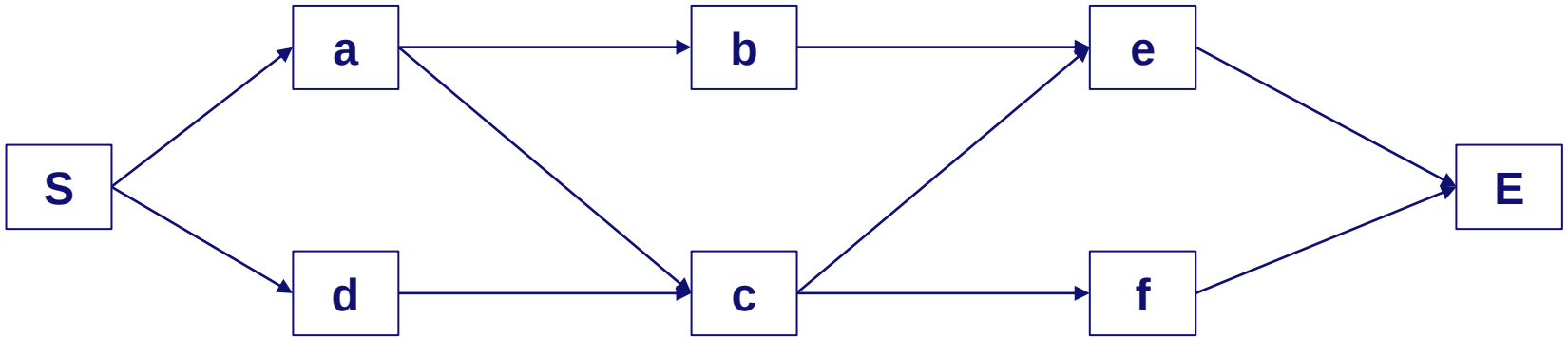
$\lvert >_L \rvert$	S	a	b	c	d	e	f	E
S	0	22	0	0	23	0	0	0
a	0	0	10	12	0	0	0	0
b	0	0	0	0	0	10	8	0
c	0	0	0	0	0	12	15	0
d	0	0	8	15	0	0	0	0
e	0	0	0	0	0	0	0	22
f	0	0	0	0	0	0	0	23
E	0	0	0	0	0	0	0	0

$\lvert \Rightarrow_L \rvert$	S	a	b	c	d	e	f	E
S	0	0.96	0	0	0.96	0	0	0
a	0	0	0.91	0.92	0	0	0	0
b	0	0	0	0	0	0.91	0.89	0
c	0	0	0	0	0	0.92	0.94	0
d	0	0	0.89	0.94	0	0	0	0
e	0	0	0	0	0	0	0	0.96
f	0	0	0	0	0	0	0	0.96
E	0	0	0	0	0	0	0	0

Heuristic Miner
Solution Q3 b)

$$L_1 = [\langle \boldsymbol{S}, a, b, e, \boldsymbol{E} \rangle^{10}, \langle \boldsymbol{S}, a, c, e, \boldsymbol{E} \rangle^{12}, \langle \boldsymbol{S}, d, b, f, \boldsymbol{E} \rangle^{8}, \langle \boldsymbol{S}, d, c, f, \boldsymbol{E} \rangle^{15}]$$

b) Construct the dependency graph with the follwoing thresholds:
At least 10 direct successions and a dependency of at least 0.9.



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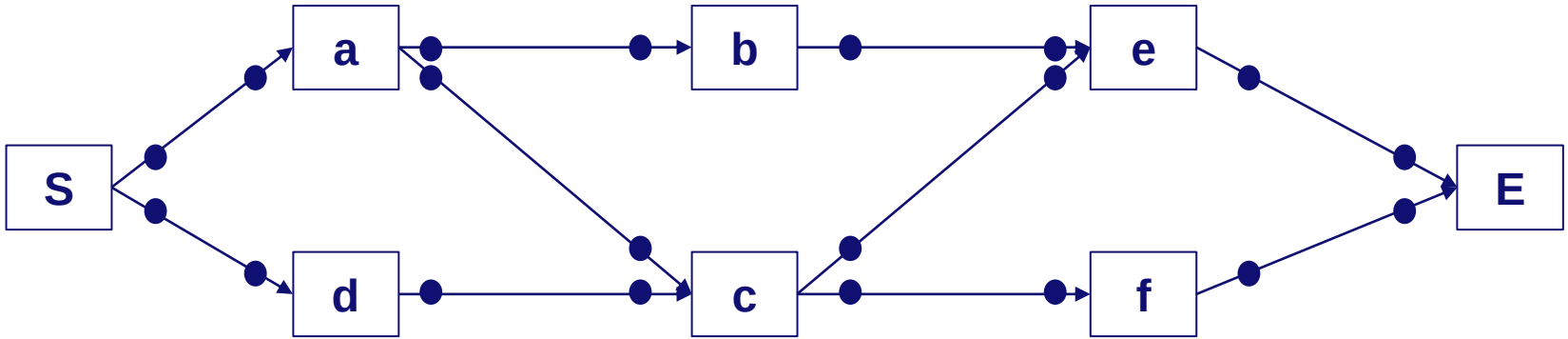
Heuristic Miner
Solution Q3 c)

$$L_1 = [\langle \boldsymbol{S}, a, b, e, \boldsymbol{E} \rangle^{10}, \langle \boldsymbol{S}, a, c, e, \boldsymbol{E} \rangle^{12}, \langle \boldsymbol{S}, d, b, f, \boldsymbol{E} \rangle^{8}, \langle \boldsymbol{S}, d, c, f, \boldsymbol{E} \rangle^{15}]$$

c) Construct the C-net based on the dependency graph. Use a window size of 2.

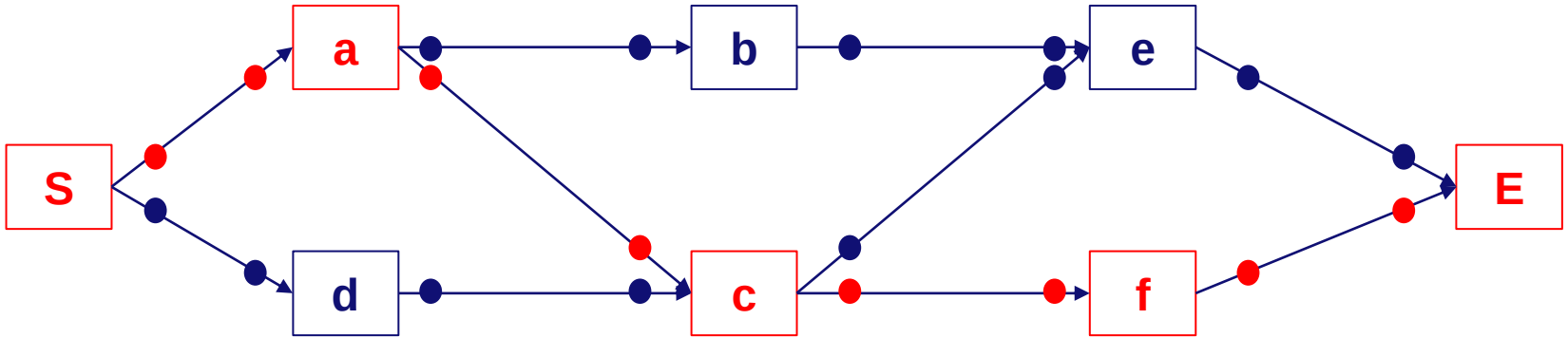


Heuristic Miner
Solution Q3 d)

$$L_1 = [\langle \boldsymbol{S}, a, b, e, \boldsymbol{E} \rangle^{10}, \langle \boldsymbol{S}, a, c, e, \boldsymbol{E} \rangle^{12}, \langle \boldsymbol{S}, d, b, f, \boldsymbol{E} \rangle^{8}, \langle \boldsymbol{S}, d, c, f, \boldsymbol{E} \rangle^{15}]$$

d) Give an activity sequence that is possible in the C-net, but is not included in the event log.

$\langle \boldsymbol{S}, a, c, f, \boldsymbol{E} \rangle$



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Question 4

$$L_2 = [\langle a, c, d \rangle^{45}, \langle b, c, d \rangle^{42}, \langle a, c, e \rangle^{38}, \langle b, c, e \rangle^{22}]$$

a) Compute the dependency measures matrix.

b) Construct the dependency graph with the following thresholds: At least 30 direct successions and a dependency of at least 0.8.

c) Construct the C-net based on the dependency graph. Use a window size of 2.

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Solution Q4

$$L_2 = [\langle a, c, d\rangle^{45}, \langle b, c, d\rangle^{42}, \langle a, c, e\rangle^{38}, \langle b, c, e\rangle^{22}]$$

$$\rightarrow [\langle \boldsymbol{S}, a, c, d, \boldsymbol{E}\rangle^{45}, \langle \boldsymbol{S}, b, c, d, \boldsymbol{E}\rangle^{42}, \langle \boldsymbol{S}, a, c, e, \boldsymbol{E}\rangle^{38}, \langle \boldsymbol{S}, b, c, e, \boldsymbol{E}\rangle^{22}]$$

Non-unique starting and ending activities → add artificial start and end.

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Solution Q4 a)

$$L_2 = [\langle \boldsymbol{S}, a, c, d, \boldsymbol{E} \rangle^{45}, \langle \boldsymbol{S}, b, c, d, \boldsymbol{E} \rangle^{42}, \langle \boldsymbol{S}, a, c, e, \boldsymbol{E} \rangle^{38}, \langle \boldsymbol{S}, b, c, e, \boldsymbol{E} \rangle^{22}]$$

a) Compute the dependency measures matrix.

Step 1: Count direct successions

$\lvert >_L \rvert$	S	a	b	c	d	e	E
S	0	83	64	0	0	0	0
a	0	0	0	83	0	0	0
b	0	0	0	64	0	0	0
c	0	0	0	0	87	60	0
d	0	0	0	0	0	0	87
e	0	0	0	0	0	0	60
E	0	0	0	0	0	0	0

Step 2: Calculate dependencies

$\lvert \Rightarrow_L \rvert$	S	a	b	c	d	e	E
S	0	0.99	0.98	0	0	0	0
a	0	0	0	0.99	0	0	0
b	0	0	0	0.98	0	0	0
c	0	0	0	0	0.99	0.98	0
d	0	0	0	0	0	0	0.99
e	0	0	0	0	0	0	0.98
E	0	0	0	0	0	0	0

Heuristic Miner

Solution Q4 b)

$$L_2 = [\langle \boldsymbol{S}, a, c, d, \boldsymbol{E} \rangle^{45}, \langle \boldsymbol{S}, b, c, d, \boldsymbol{E} \rangle^{42}, \langle \boldsymbol{S}, a, c, e, \boldsymbol{E} \rangle^{38}, \langle \boldsymbol{S}, b, c, e, \boldsymbol{E} \rangle^{22}]$$

b) Construct the dependency graph with the following thresholds:
At least 30 direct successions and a dependency of at least 0.8.

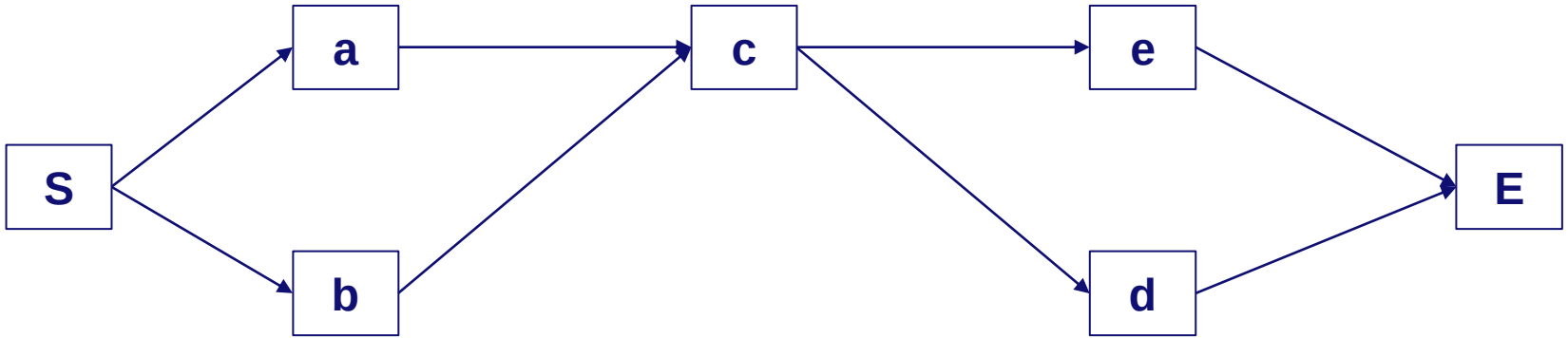
$\lvert >_L \rvert$	S	a	b	c	d	e	E
S	0	83	64	0	0	0	0
a	0	0	0	83	0	0	0
b	0	0	0	64	0	0	0
c	0	0	0	0	87	60	0
d	0	0	0	0	0	0	87
e	0	0	0	0	0	0	60
E	0	0	0	0	0	0	0

$\lvert \Rightarrow_L \rvert$	S	a	b	c	d	e	E
S	0	0.99	0.98	0	0	0	0
a	0	0	0	0.99	0	0	0
b	0	0	0	0.98	0	0	0
c	0	0	0	0	0.99	0.98	0
d	0	0	0	0	0	0	0.99
e	0	0	0	0	0	0	0.98
E	0	0	0	0	0	0	0

Heuristic Miner
Solution Q4 b)

$$L_2 = [\langle \boldsymbol{S}, a, c, d, \boldsymbol{E} \rangle^{45}, \langle \boldsymbol{S}, b, c, d, \boldsymbol{E} \rangle^{42}, \langle \boldsymbol{S}, a, c, e, \boldsymbol{E} \rangle^{38}, \langle \boldsymbol{S}, b, c, e, \boldsymbol{E} \rangle^{22}]$$

b) Construct the dependency graph with the following thresholds:
At least 30 direct successions and a dependency of at least 0.8.



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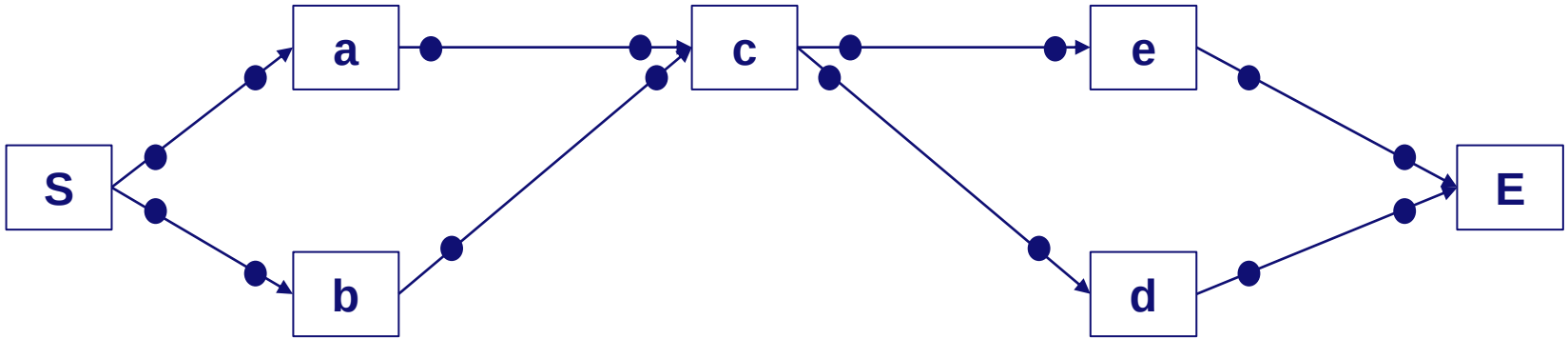
Solution Q4 c)

$$L_2 = [\langle \boldsymbol{S}, a, c, d, \boldsymbol{E} \rangle^{45}, \langle \boldsymbol{S}, b, c, d, \boldsymbol{E} \rangle^{42}, \langle \boldsymbol{S}, a, c, e, \boldsymbol{E} \rangle^{38}, \langle \boldsymbol{S}, b, c, e, \boldsymbol{E} \rangle^{22}]$$

c) Construct the C-net based on the dependency graph. Use a window size of 2.



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Question 5

$$L_3 = [\langle a, b, e, f \rangle^2, \langle a, b, e, c, d, b, f \rangle^3, \langle a, b, c, e, d, b, f \rangle^2, \langle a, b, c, d, e, b, f \rangle^4, \langle a, e, b, c, d, b, f \rangle^3]$$

a) Compute the dependency measures matrix.

b) Construct the dependency graph with the follwoing thresholds: At least 10 direct successions and a dependency of at least 0.8.

c) Construct the C-net based on the dependency graph. Use a window size of 2.

d) Give an activity sequence that is possible in the C-net but is not included in the event log.

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Solution Q5

$$L_3 = [\langle a,b,e,f\rangle^2, \langle a,b,e,c,d,b,f\rangle^3, \langle a,b,c,e,d,b,f\rangle^2, \langle a,b,c,d,e,b,f\rangle^4, \langle a,e,b,c,d,b,f\rangle^3]$$

Unique start activity *a* and unique end activity *f* already there.

a) Compute the dependency measures matrix.

b) Construct the dependency graph with the follwoing thresholds: At least 10 direct successions and a dependency of at least 0.8.

c) Construct the C-net based on the dependency graph. Use a window size of 2.

d) Give an activity sequence that is possible in the C-net but is not included in the event log.

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Solution Q5 a)

$$L_3 = [\langle a,b,e,f\rangle^2, \langle a,b,e,c,d,b,f\rangle^3, \langle a,b,c,e,d,b,f\rangle^2, \langle a,b,c,d,e,b,f\rangle^4, \langle a,e,b,c,d,b,f\rangle^3]$$

a) Compute the dependency measures matrix.

Step 1: Count direct successions

$\|>_L\|$	a	b	c	d	e	f
a	0	**11**	0	0	**3**	0
b	0	0	**9**	0	**5**	**12**
c	0	0	0	**10**	**2**	0
d	0	**8**	0	0	**4**	0
e	0	**7**	**3**	**2**	0	**2**
f	0	0	0	0	0	0

Negative dependencies are discarded.

Step 2: Calculate dependencies

$$|a \Rightarrow_L b| = \begin{cases} \dfrac{|a >_L b| - |b >_L a|}{|a >_L b| + |b >_L a| + 1} & \text{if } a \neq b \\ \dfrac{|a >_L a|}{|a >_L a| + 1} & \text{if } a = b \end{cases}$$

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Solution Q5 a)

$$L_3 = [\langle a,b,e,f\rangle^2, \langle a,b,e,c,d,b,f\rangle^3, \langle a,b,c,e,d,b,f\rangle^2, \langle a,b,c,d,e,b,f\rangle^4, \langle a,e,b,c,d,b,f\rangle^3]$$

a) Compute the dependency measures matrix.

Step 1: Count direct successions

$\lvert >_L \rvert$	a	b	c	d	e	f
a	0	**11**	0	0	**3**	0
b	0	0	**9**	0	**5**	**12**
c	0	0	0	**10**	**2**	0
d	0	**8**	0	0	**4**	0
e	0	**7**	**3**	**2**	0	**2**
f	0	0	0	0	0	0

Step 2: Calculate dependencies

$\lvert \Rightarrow_L \rvert$	a	b	c	d	e	f
a	0	0.92	0	0	0.75	0
b	0	0	0.9	0	0	0.92
c	0	0	0	0.91	0	0
d	0	0.89	0	0	0.29	0
e	0	0.15	0.17	0	0	0.67
f	0	0	0	0	0	0

Negative dependencies are discarded.

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Solution Q5 b)

b) Construct the dependency graph with the following thresholds: At least 10 direct successions and a dependency of at least 0.8.

$\|>_L\|$	a	b	c	d	e	f
a	0	11	0	0	3	0
b	0	0	9	0	5	12
c	0	0	0	10	2	0
d	0	8	0	0	4	0
e	0	7	3	2	0	2
f	0	0	0	0	0	0

$\|\Rightarrow_L\|$	a	b	c	d	e	f
a	0	0.92	0	0	0.75	0
b	0	0	0.9	0	0	0.92
c	0	0	0	0.91	0	0
d	0	0.89	0	0	0.29	0
e	0	0.15	0.17	0	0	0.67
f	0	0	0	0	0	0

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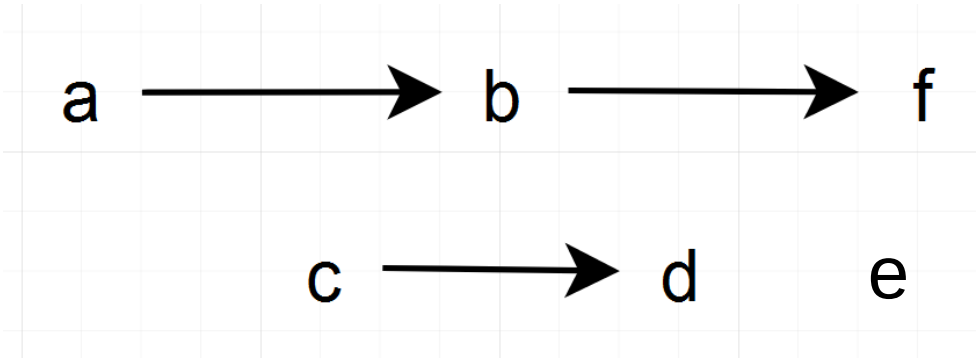
Solution Q5 b)

$$L_3 = [\langle a, b, e, f \rangle^2, \langle a, b, e, c, d, b, f \rangle^3, \langle a, b, c, e, d, b, f \rangle^2, \langle a, b, c, d, e, b, f \rangle^4, \langle a, e, b, c, d, b, f \rangle^3]$$

b) Construct the dependency graph with the follwoing thresholds: At least 10 direct successions and a dependency of at least 0.8.

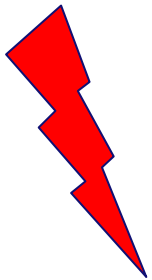


Heuristic Miner

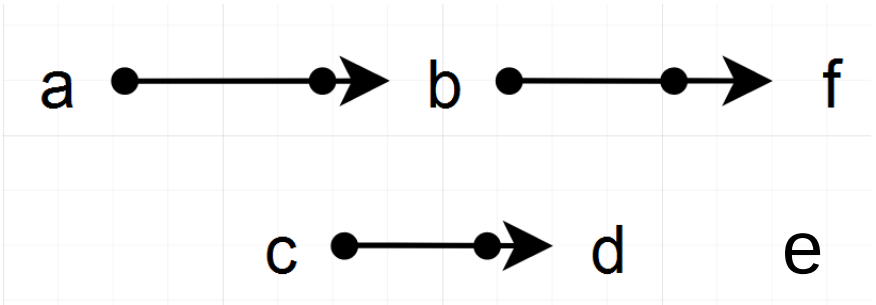
Solution Q5 c)

$$L_3 = [\langle a, b, e, f \rangle^2, \langle a, b, e, c, d, b, f \rangle^3, \langle a, b, c, e, d, b, f \rangle^2, \langle a, b, c, d, e, b, f \rangle^4, \langle a, e, b, c, d, b, f \rangle^3]$$

c) Construct the C-net based on the dependency graph. Use a window size of 2.



C-nets need a unique start and unique end activity!
→ Refinements of Heuristic Miner can fix this



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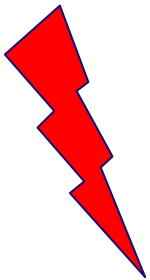
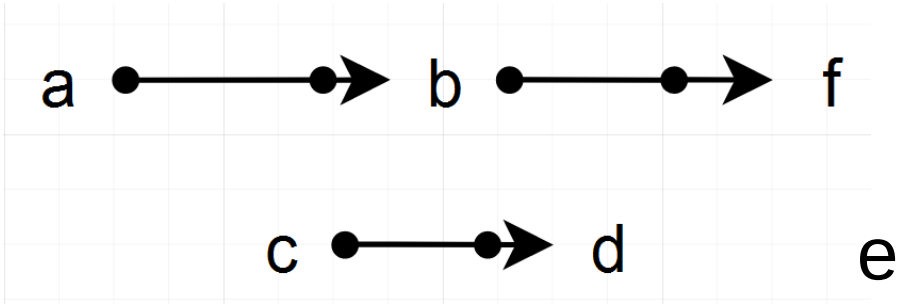
Solution Q5 c)

$$L_3 = [\langle a, b, e, f \rangle^2, \langle a, b, e, c, d, b, f \rangle^3, \langle a, b, c, e, d, b, f \rangle^2, \langle a, b, c, d, e, b, f \rangle^4, \langle a, e, b, c, d, b, f \rangle^3]$$

d) Give an activity sequence that is possible in the C-net but is not included in the event log.



(not a C-Net)

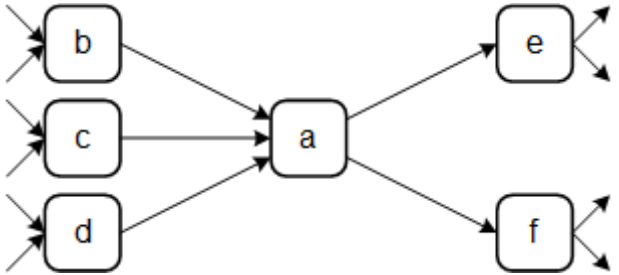


Heuristic Mining

Question 6 a)

Consider the partial traces and the fragment of a dependency graph shown below. Add the input and output bindings for activity ***a*** based on the partial traces. Use window size of 5 and no thresholds.

<...c,l,b,k,c,l,m,a,e,f,l,l,k,n,m...>
<...d,m,l,m,d,k,k,a,f,e,l,l,l,k,m...>
<...a,b,l,c,m,d,l,a,f,k,l,m,n,m,l...>
<...d,k,b,c,l,k,m,a,f,l,l,m,k,l,k...>
<...k,l,b,c,d,l,k,a,e,k,l,m,n,m,f...>

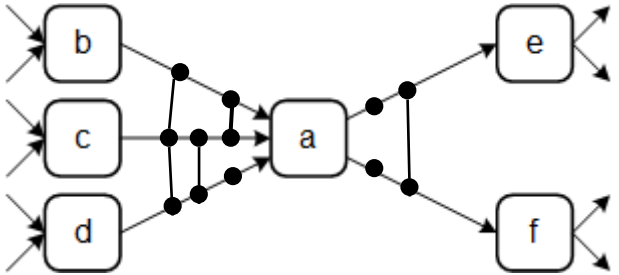


Heuristic Mining

Solution 6 a)

Consider the partial traces and the fragment of a dependency graph shown below. Add the input and output bindings for activity ***a*** based on the partial traces. Use window size of 5 and no thresholds.

<...c,l,b,k,c,l,m,a,e,f,l,l,k,n,m...>
<...d,m,l,m,d,k,k,a,f,e,l,l,l,k,m...>
<...a,b,l,c,m,d,l,a,f,k,l,m,n,m,l...>
<...d,k,b,c,l,k,m,a,f,l,l,m,k,l,k...>
<...k,l,b,c,d,l,k,a,e,k,l,m,n,m,f...>

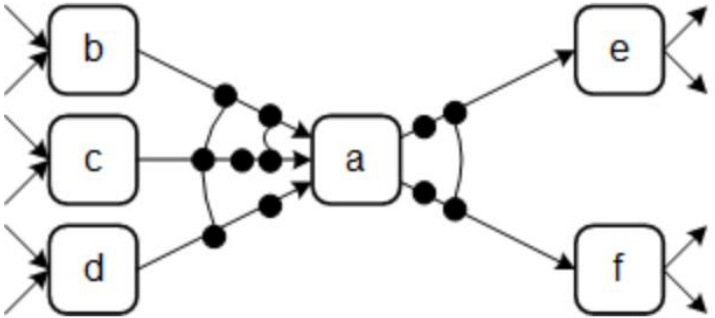


Heuristic Mining

Question 6 b)

Consider the partial traces below and assume a window size of 5 and no thesholds. Which input and output bindings of the activity ***a*** in the (partial) C-Net below are **incorrect** and why?

<...c,l,b,k,c,l,m,a,e,f,l,l,k,n,m...>
<...d,m,l,m,d,k,k,a,f,e,l,l,l,k,m...>
<...a,b,l,c,m,d,l,a,f,k,l,m,n,m,l...>
<...d,k,b,c,l,k,m,a,f,l,l,m,k,l,k...>
<...k,l,b,c,d,l,k,a,e,k,l,m,n,m,f...>

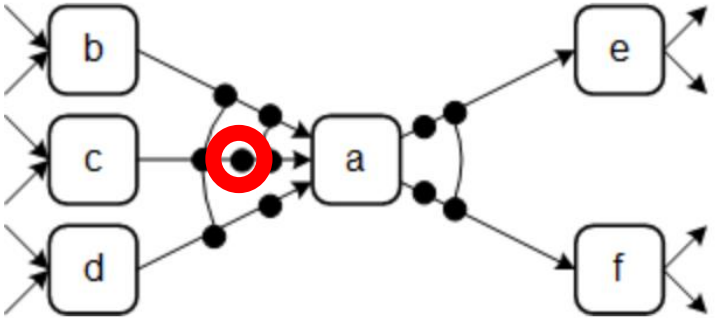


Heuristic Mining

Solution 6 b)

Consider the partial traces below and assume a window size of 5 and no thesholds. Which input and output bindings of the activity ***a*** in the (partial) C-Net below are **incorrect** and why?

<...c,l,b,k,c,l,m,a,e,f,l,l,k,n,m...>
<...d,m,l,m,d,k,k,a,f,e,l,l,l,k,m...>
<...a,b,l,c,m,d,l,a,f,k,l,m,n,m,l...>
<...d,k,b,c,l,k,m,a,f,l,l,m,k,l,k...>
<...k,l,b,c,d,l,k,a,e,k,l,m,n,m,f...>



Activity *a* cannot happen after just activity *c* in the traces, but it can in the c-net.

State-based regions

Transition System

Question 1

$$L_2 = [\langle a, c, d \rangle, \langle b, c, d \rangle, \langle a, c, e \rangle, \langle b, c, e \rangle]$$

Given the event log above, create a transitions system using the following abstractions:

a) past with sequence abstraction

b) past with multiset abstraction

c) only last event abstraction

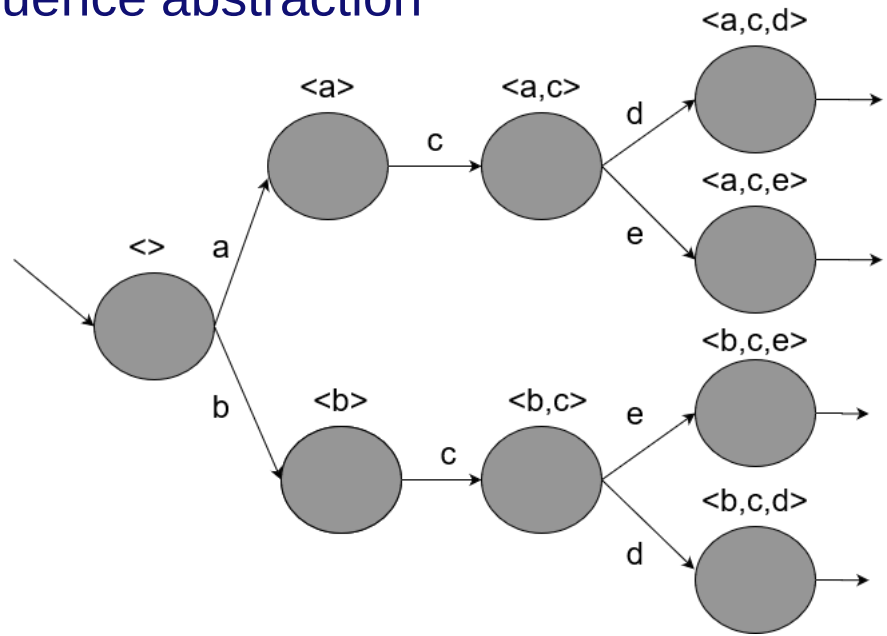
d) future with sequence abstraction

Transition System

Solution Q1 a)

$$L_2 = [\langle a, c, d \rangle, \langle b, c, d \rangle, \langle \mathrm{a}, c, e \rangle, \langle b, c, e \rangle]$$

a) past with sequence abstraction

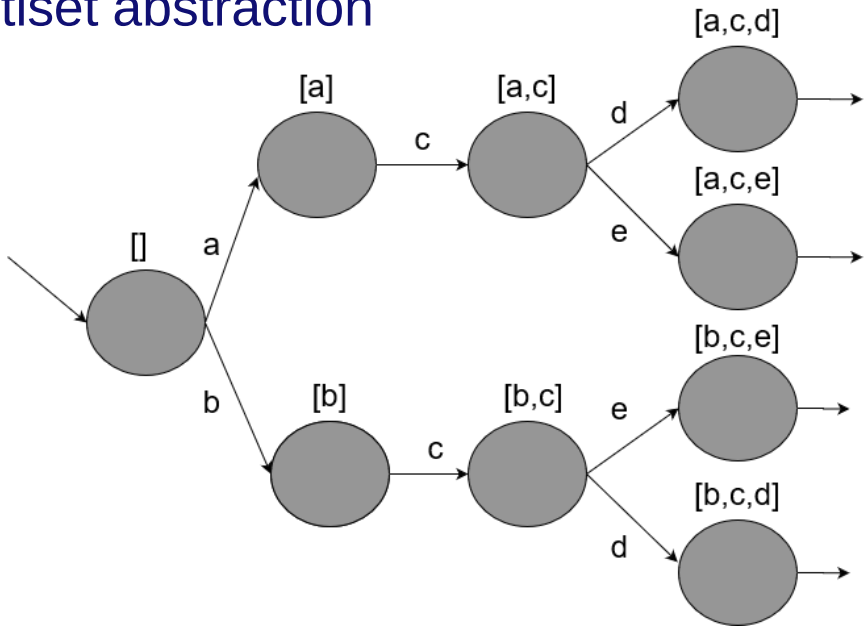


Transition System

Solution Q1 b)

$$L_2 = [\langle a, c, d \rangle, \langle b, c, d \rangle, \langle a, c, e \rangle, \langle b, c, e \rangle]$$

b) past with multiset abstraction



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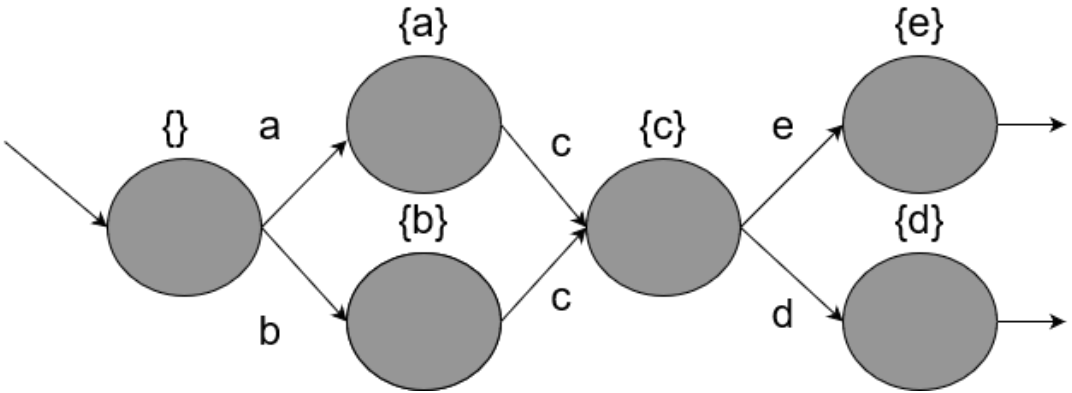
Transition System
Solution Q1 c)

$$L_2 = [\langle a, c, d \rangle, \langle b, c, d \rangle, \langle a, c, e \rangle, \langle b, c, e \rangle]$$

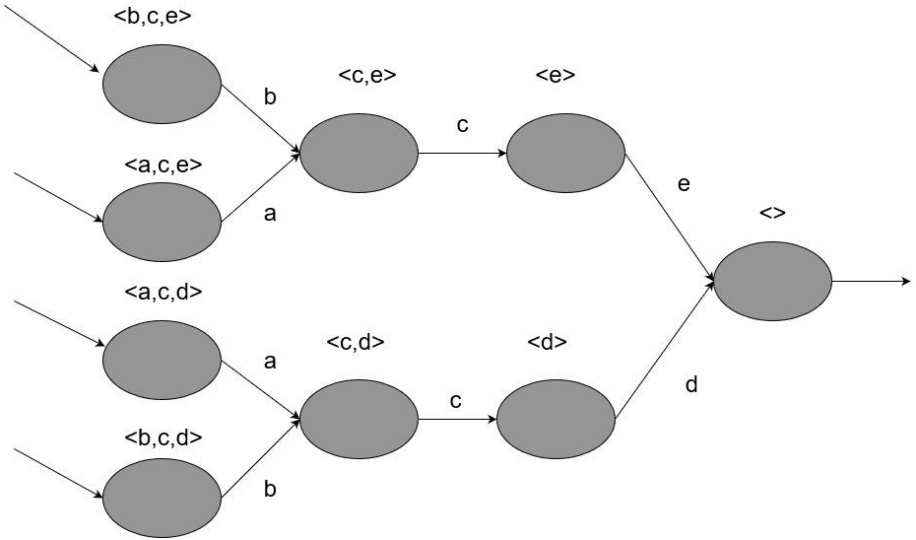
c) only last event abstraction



Transition System
Solution Q1 d)

$$L_2 = [\langle a, c, d \rangle, \langle b, c, d \rangle, \langle a, c, e \rangle, \langle b, c, e \rangle]$$

d) future with sequence abstraction



Transition System

Question 2

$$L_5 = [\langle a, c, d, f \rangle, \langle a, d, c, f \rangle, \langle b, c, e, f \rangle, \langle b, e, c, f \rangle]$$

Given the event log above, create a transitions system using the following abstractions:

a) past with set abstraction

b) past with multiset abstraction

c) only last event abstraction

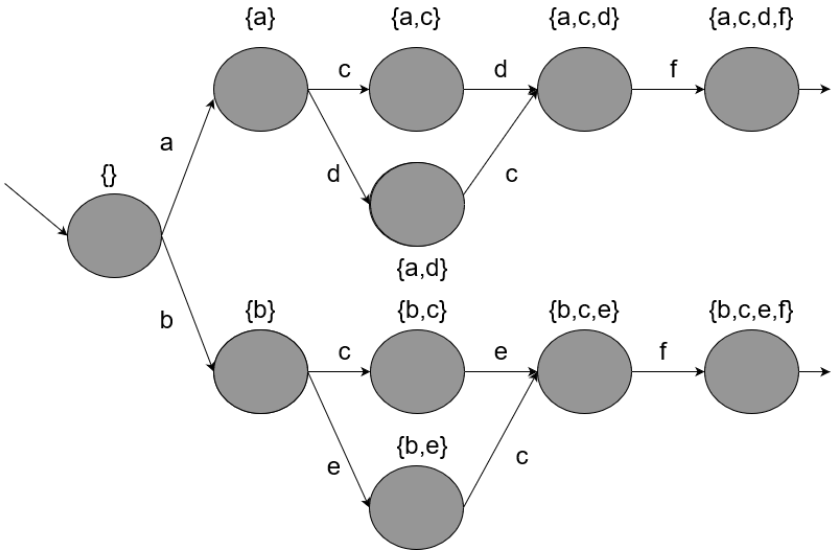
d) future with sequence abstraction

Transition System

Solution Q2 a)

$$L_5 = [\langle a, c, d, f \rangle, \langle a, d, c, f \rangle, \langle b, c, e, f \rangle, \langle b, e, c, f \rangle]$$

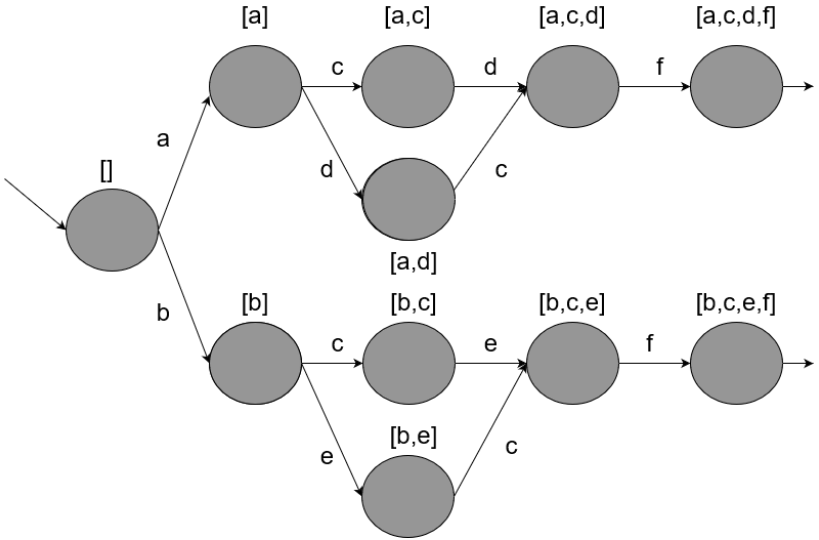
a) past with set abstraction



Transition System
Solution Q2 b)

$$L_5 = [\langle a, c, d, f \rangle, \langle a, d, c, f \rangle, \langle b, c, e, f \rangle, \langle b, e, c, f \rangle]$$

b) past with multiset abstraction



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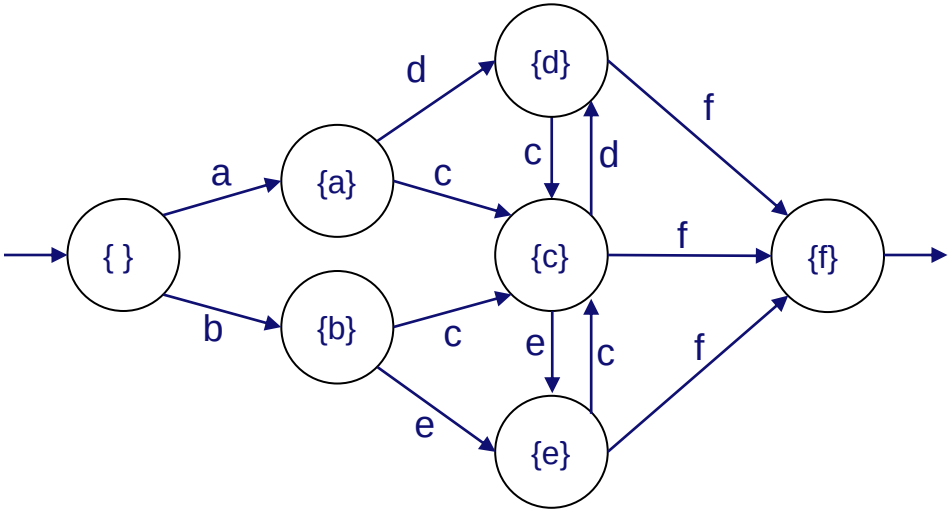
Transition System

Solution Q2 c)

$$L_5 = [\langle a, c, d, f \rangle, \langle a, d, c, f \rangle, \langle b, c, e, f \rangle, \langle b, e, c, f \rangle]$$

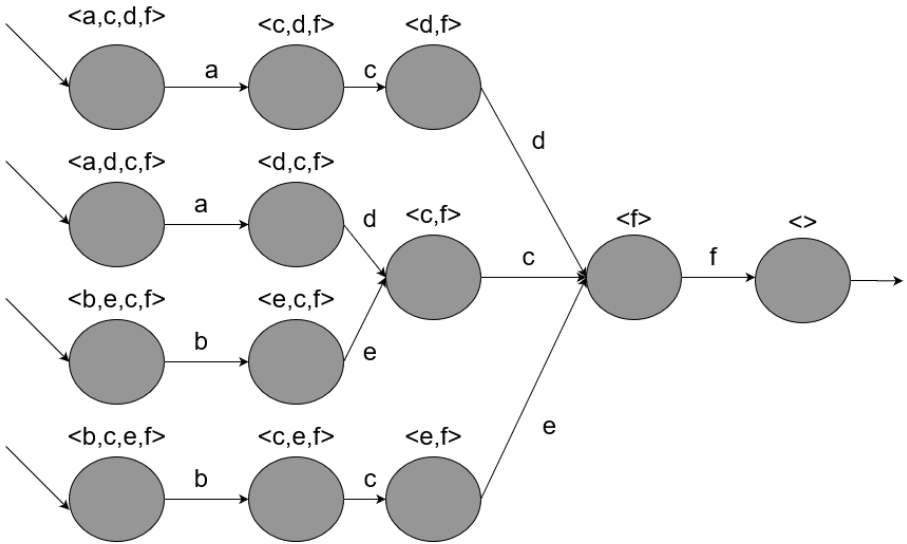
c) only last event abstraction



Transition System
Solution Q2 d)

$$L_5 = [\langle a, c, d, f \rangle, \langle a, d, c, f \rangle, \langle b, c, e, f \rangle, \langle b, e, c, f \rangle]$$

d) future with sequence abstraction



Regions
Question 3

$$L_2 = [\langle a, c, d \rangle, \langle b, c, d \rangle, \langle a, c, e \rangle, \langle b, c, e \rangle]$$

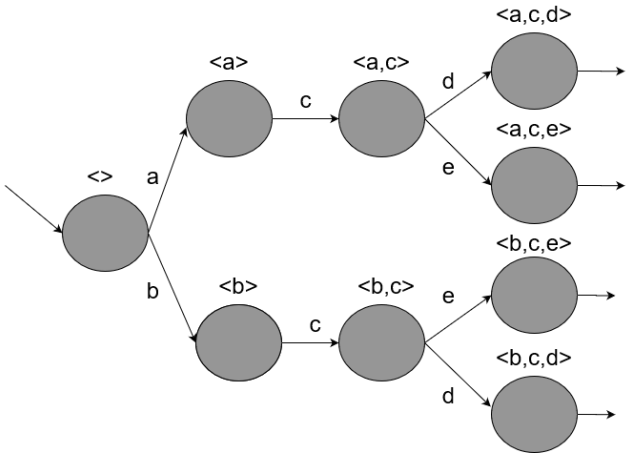
a) Create a transition system and detect **all** its regions using the past with sequence abstraction.

b) Create a transition system and detect its non-trivial minimal regions using the only last event abstraction.

Regions
Solution Q3 a)

$$L_2 = [\langle a, c, d \rangle, \langle b, c, d \rangle, \langle a, c, e \rangle, \langle b, c, e \rangle]$$

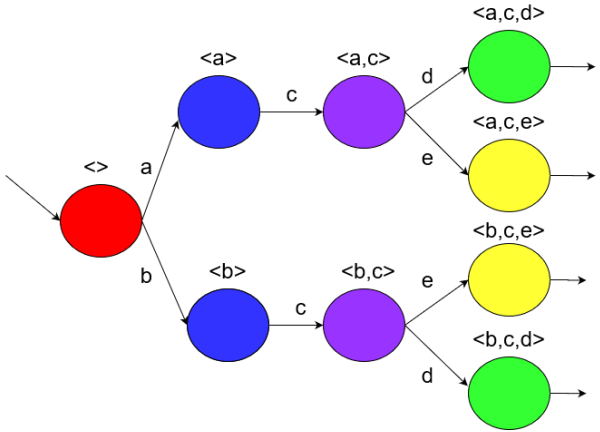
a) past with sequence abstraction (see Q1a)

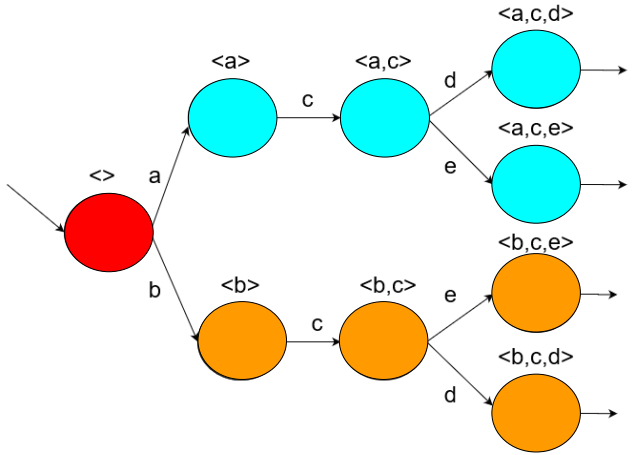


Regions
Solution Q3 a)

$$L_2 = [\langle a, c, d \rangle, \langle b, c, d \rangle, \langle a, c, e \rangle, \langle b, c, e \rangle]$$

a) past with sequence abstraction (see Q1a)



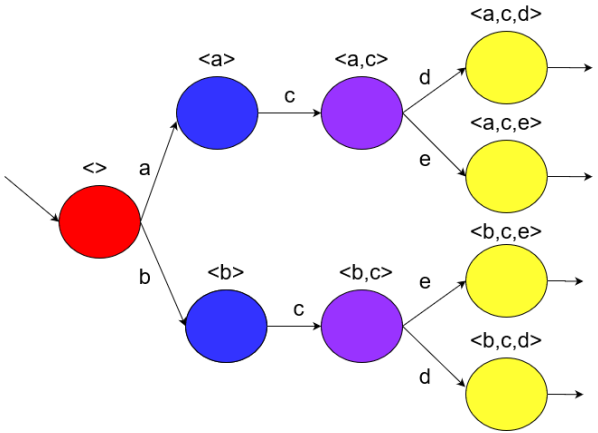


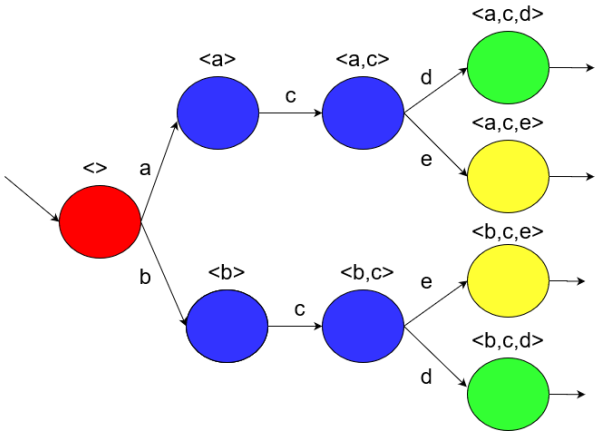
minimal regions

Regions
Solution Q3 a)

$$L_2 = [\langle a, c, d \rangle, \langle b, c, d \rangle, \langle a, c, e \rangle, \langle b, c, e \rangle]$$

a) past with sequence abstraction (other example regions)





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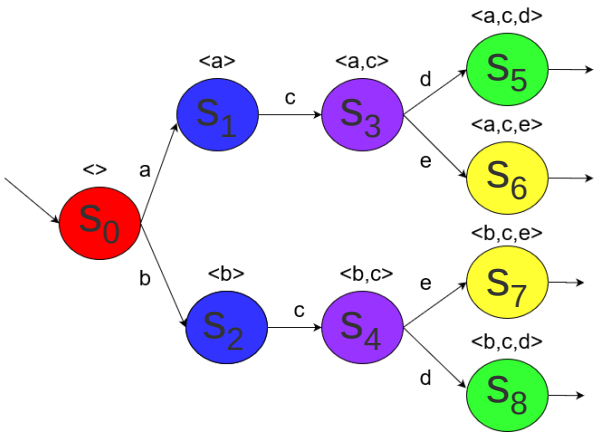
Regions
Solution Q3 a)

$$L_2 = [\langle a, c, d\rangle, \langle b, c, d\rangle, \langle a, c, e\rangle, \langle b, c, e\rangle]$$

a) past with sequence abstraction: complete list of regions



Trivial regions:
$\{\}, \{s_0, s_1, s_2, s_3, s_4, s_5, s_6, s_7, s_8\}$

Minimal regions:
$\{s_0\}, \{s_1, s_2\}, \{s_3, s_4\}, \{s_5, s_8\}, \{s_6, s_7\}, \{s_1, s_3, s_5, s_6\}, \{s_2, s_4, s7, s_8\}$

Trivial without one other region:
$\{s_1, s_2, s_3, s_4, s_5, s_6, s_7, s_8\}, \{s_0, s_3, s_4, s_5, s_6, s_7, s_8\}, \{s_0, s_1, s_2, s_5, s_6, s_7, s_8\},$
$\{s_0, s_1, s_2, s_3, s_4, s_6, s_7\}, \{s_0, s_1, s_2, s_3, s_4, s_5, s_8\}, \{s_0, s_2, s_4, s_7, s_8\}, \{s_0, s_1, s_3, s_5, s_6\}$

Trivial without two other regions:
$\{s_3, s_4, s_5, s_6, s_7, s_8\}, \{s_1, s_2, s_5, s_6, s_7, s_8\}, \{s_1, s_2, s_3, s_4, s_6, s_7\}, \{s_1, s_2, s_3, s_4, s_5, s_8\}$
$\{s_0, s_5, s_6, s_7, s_8\}, \{s_0, s_3, s_4, s_6, s_7\}, \{s_0, s_3, s_4, s_5, s_8\}, \{s_0, s_1, s_2, s_6, s_7\}, \{s_0, s_1, s_2, s_5, s_8\}$
$\{s_0, s_1, s_2, s_3, s_4\}, \{s_0\}$

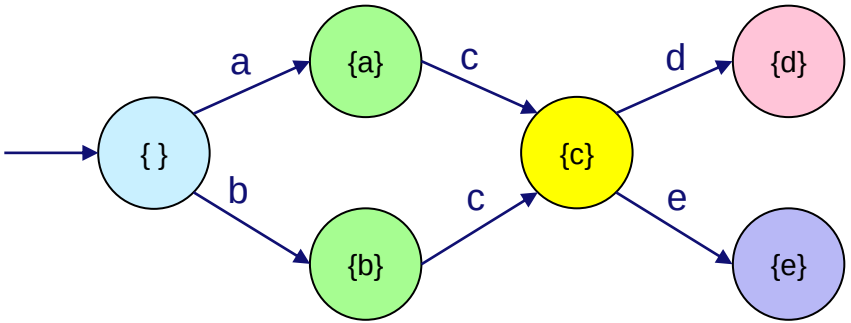
Trivial without three other regions:
$\{s_5, s_6, s_7, s_8\}, \{s_3, s_4, s_6, s_7\}, \{s_3, s_4, s_5, s_8\}, \{s_1, s_2, s_6, s_7\}, \{s_1, s_2, s_5, s_8\}, \{s_1, s_2, s_3, s_4\},$
$\{s_0, s_6, s_7\}, \{s_0, s_5, s_8\}, \{s_0, s_3, s_4\}, \{s_0, s_1, s_2\}$

Removing a subregion from a region yields another region.

Regions
Solution Q3 b)

$$L_2 = [\langle a, c, d \rangle, \langle b, c, d \rangle, \langle a, c, e \rangle, \langle b, c, e \rangle]$$

b) past with only last event abstraction: minimal regions marked

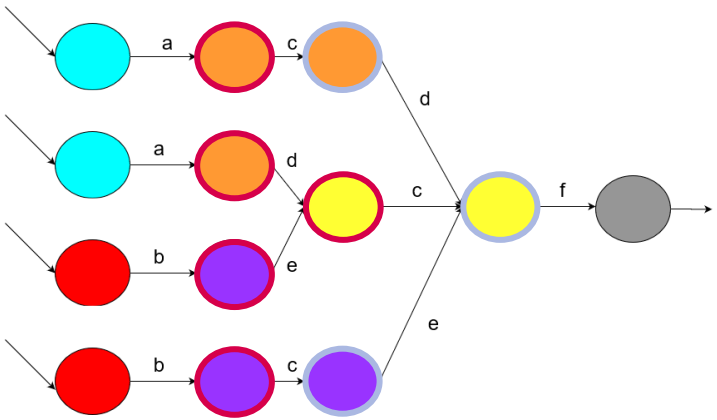


Regions
Question 4

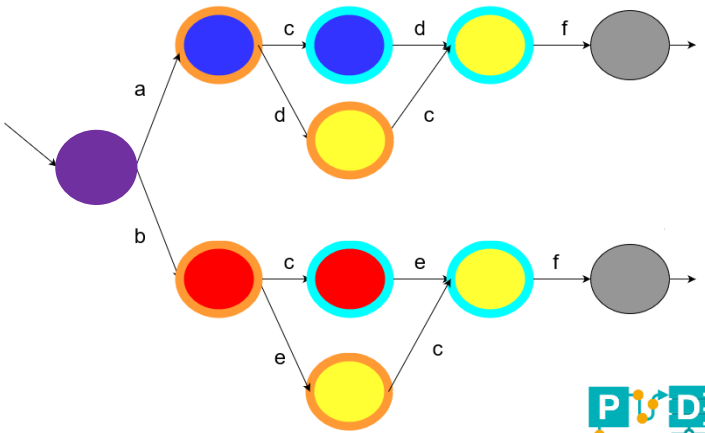
$$L_6 = [\langle a, c, d, f \rangle, \langle a, d, c, f \rangle, \langle b, c, e, f \rangle, \langle b, e, c, f \rangle]$$

Consider the following two transition systems, their non-trivial, minimal regions, and the log above. For each of them, name the applied abstraction function and provide the resulting Petri net.

a)



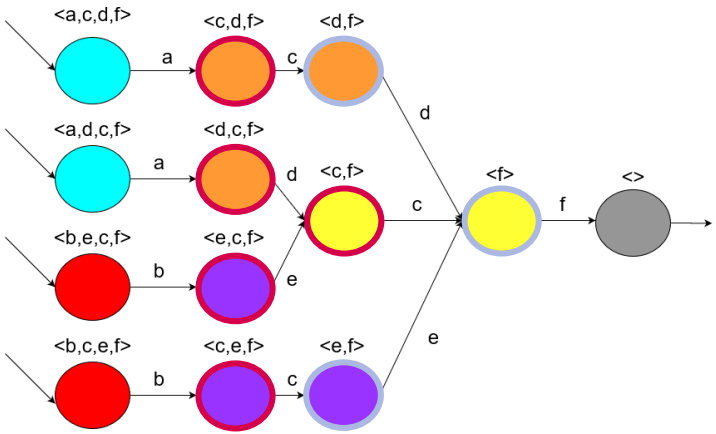
b)



Regions
Solution Q4 a)

$$L_6 = [\langle a, c, d, f \rangle, \langle a, d, c, f \rangle, \langle b, c, e, f \rangle, \langle b, e, c, f \rangle]$$

a) future with sequence abstraction

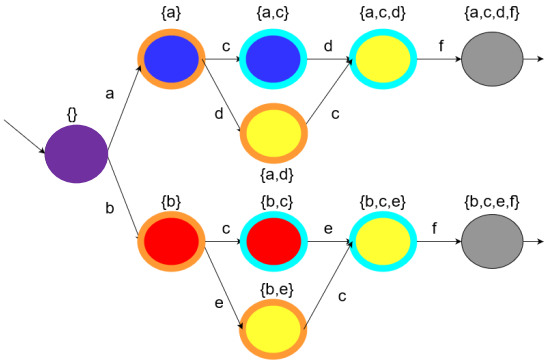


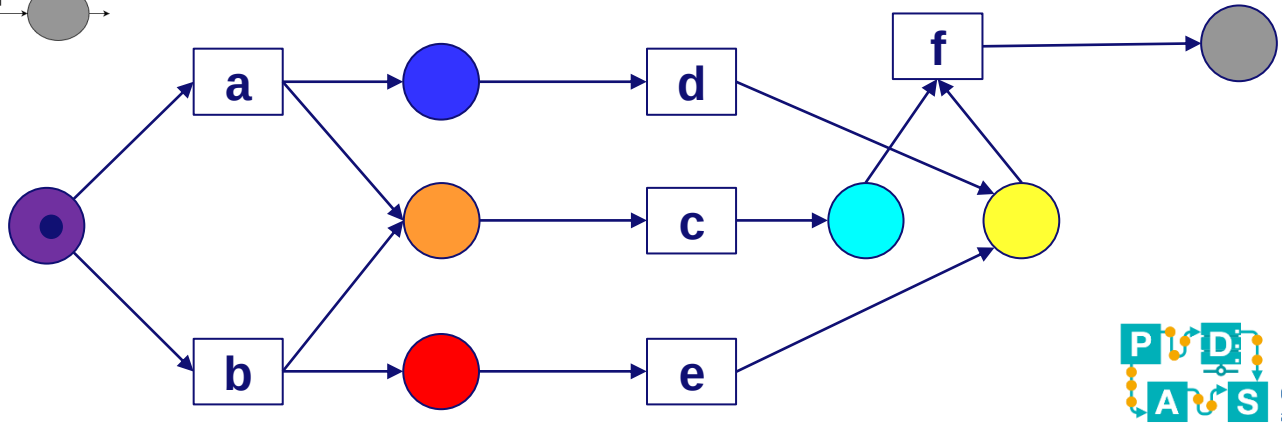
To mine state-based Regions we require a single initial state.

Regions
Solution Q4 b)

$$L_6 = [\langle a, c, d, f \rangle, \langle a, d, c, f \rangle, \langle b, c, e, f \rangle, \langle b, e, c, f \rangle]$$

b) past with set abstraction





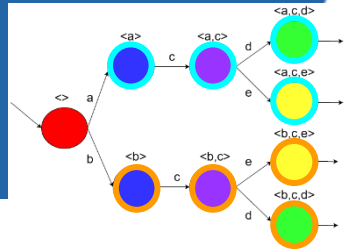
Petri net

Question 5

For the event log below, create the transition system using past with sequence abstraction. Find the non-trivial minimal regions and construct the corresponding Petri net.

$$L_2 = [\langle a, c, d \rangle, \langle b, c, d \rangle, \langle a, c, e \rangle, \langle b, c, e \rangle]$$

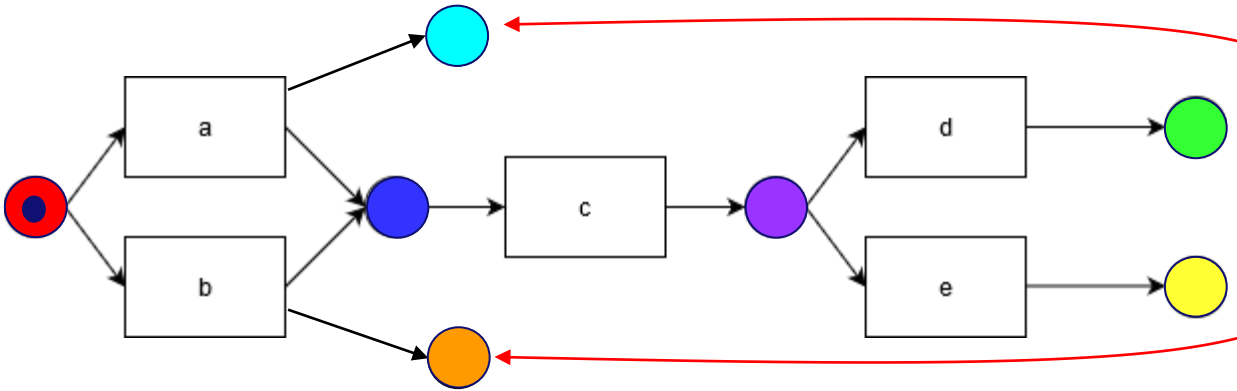
Petri net
Solution Q5



For the event log below, create the transition system using past with sequence abstraction. Find the non-trivial minimal regions and construct the corresponding Petri net.

$$L_2 = [\langle a, c, d\rangle, \langle b, c, d\rangle, \langle a, c, e\rangle, \langle b, c, e\rangle]$$

Same transitions system and minimal regions as in ‘Regions Q3’.



Note: adding artificial start and end activities can help to avoid useless places