Discovering Context-Aware Models for Predicting Business Process Performances

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Motivation

- Run-time support is an emerging topic in Process Mining research
- Business processes are very complex and flexible
- Case properties and environmental factors influence what is aimed to be predicted
- Discover context-related execution scenarios and model them via distinct state-aware transition systems.
- Case Study: Time Prediction on a Logistics Process

Structure

- Idea
- Transition Systems for event logs
- State abstraction functions
- Clustering function through a Predictive Clustering Tree
- Small running example
- Further possibilities

Discovering Context-Aware Models for Predicting Business Process Performances

Event log L = {<a,b,c,d>, <a,c,b,d>}

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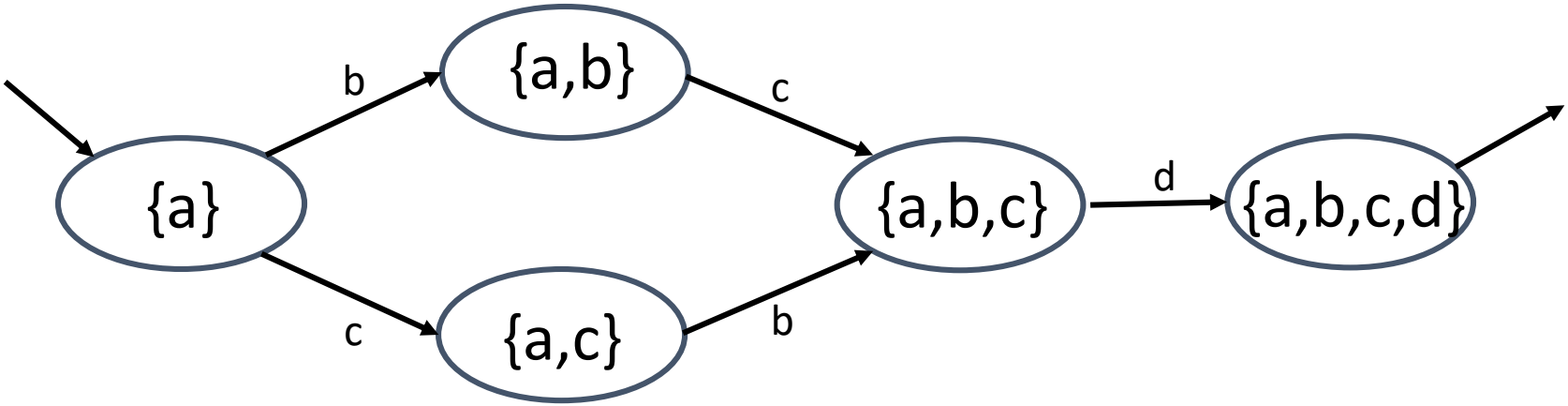

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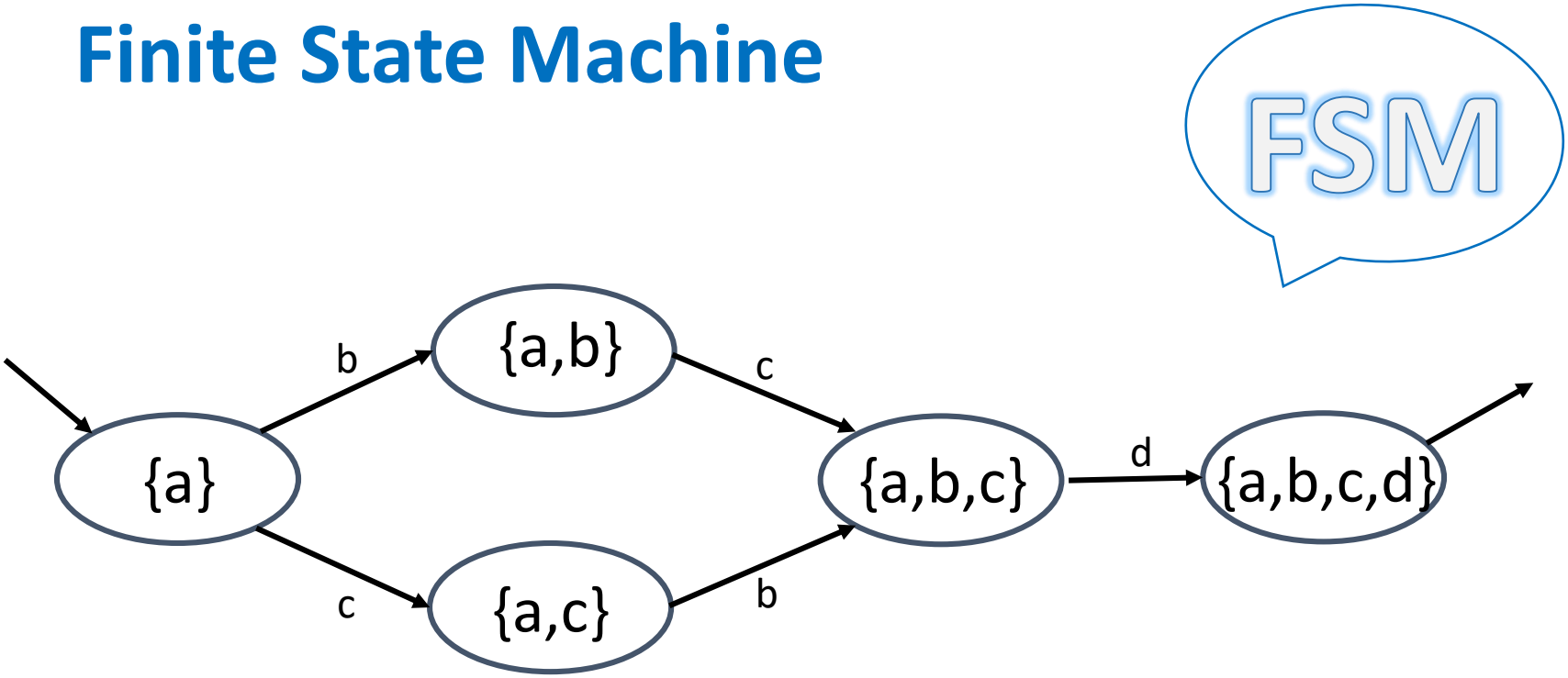
Finite State Machine



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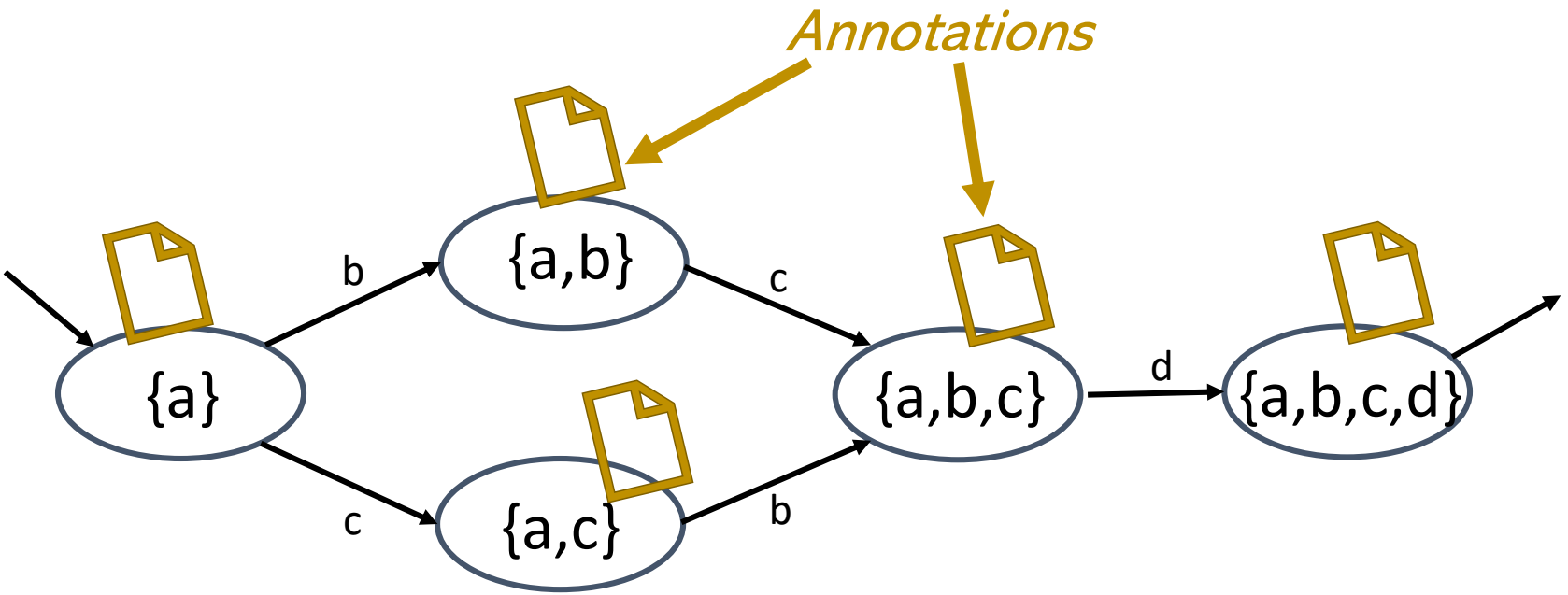

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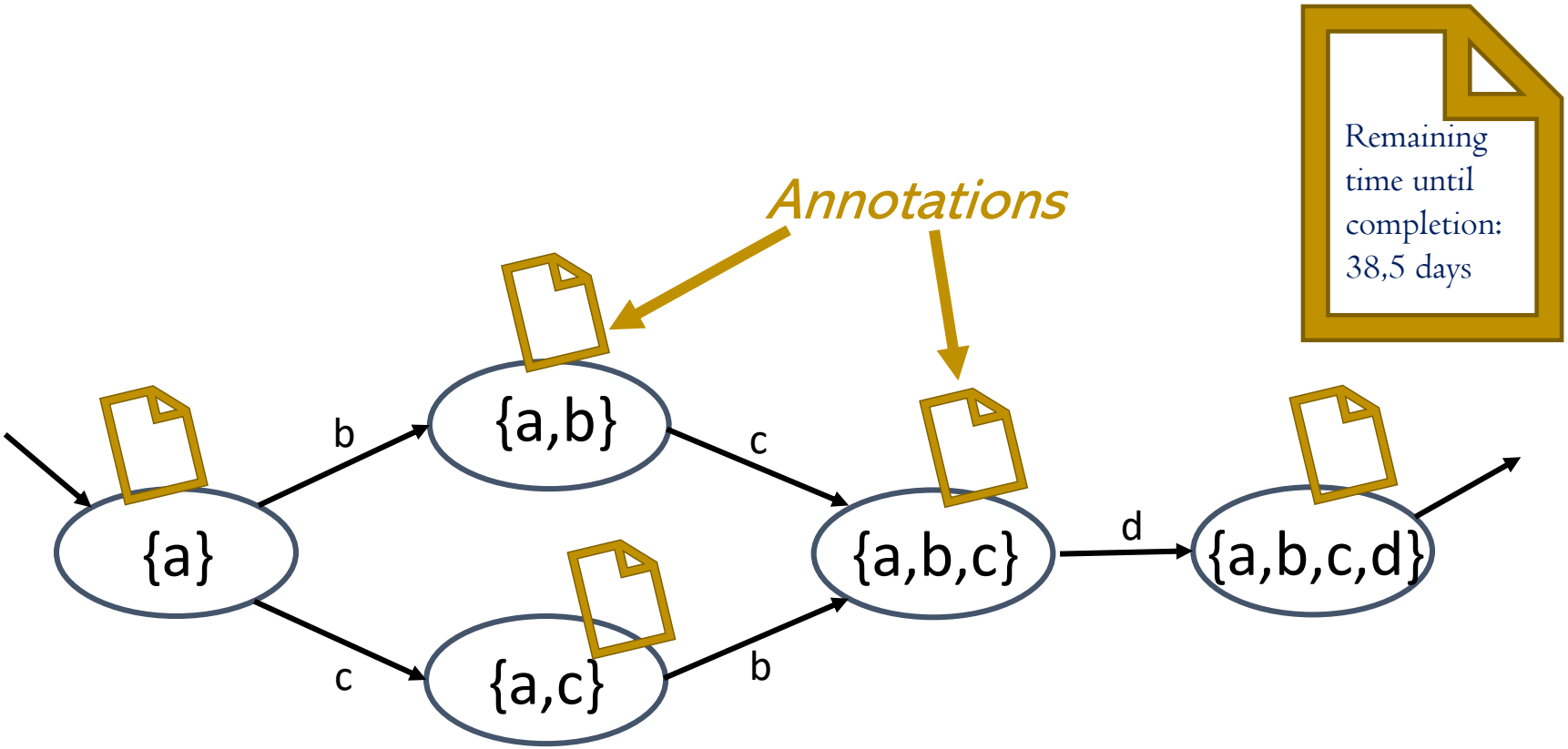

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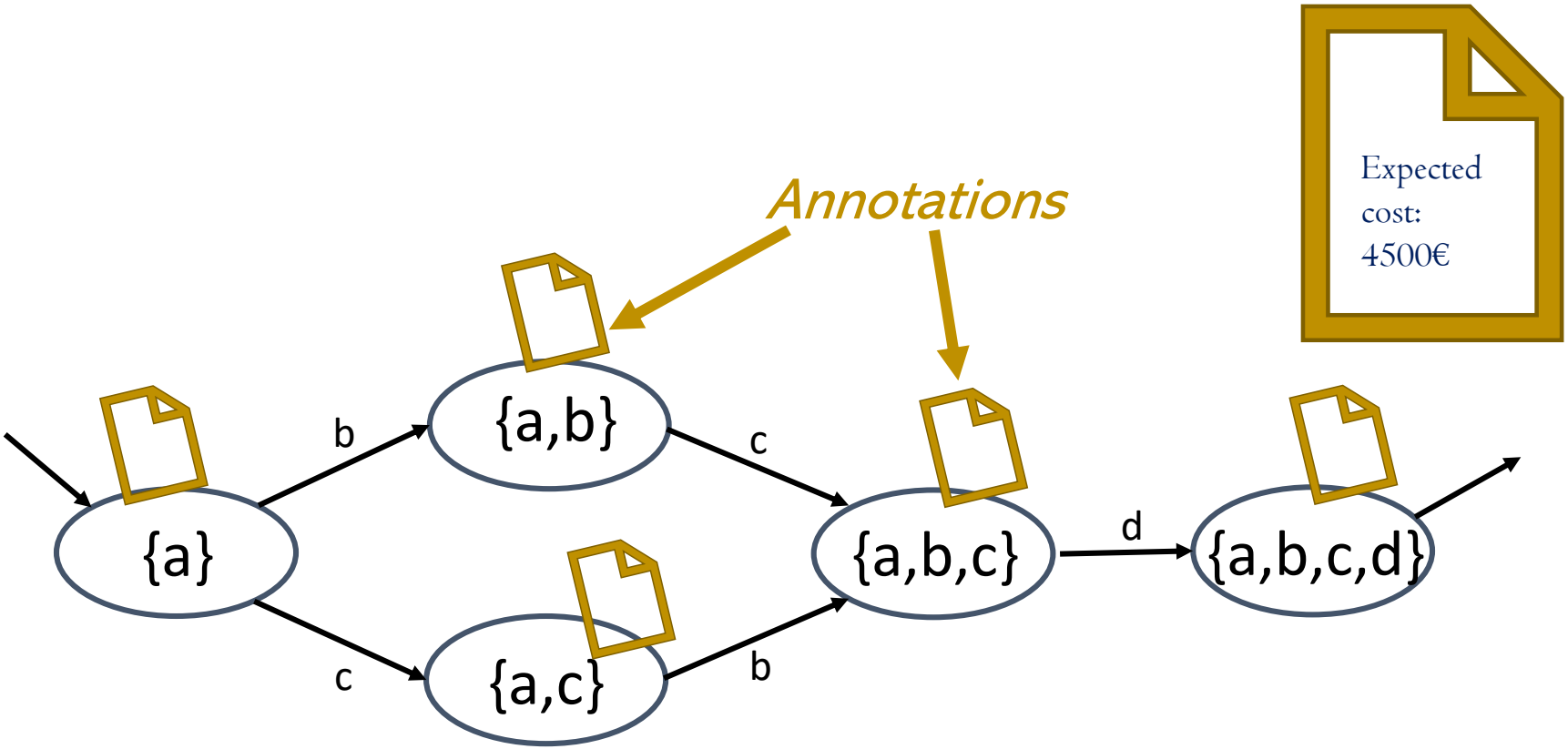

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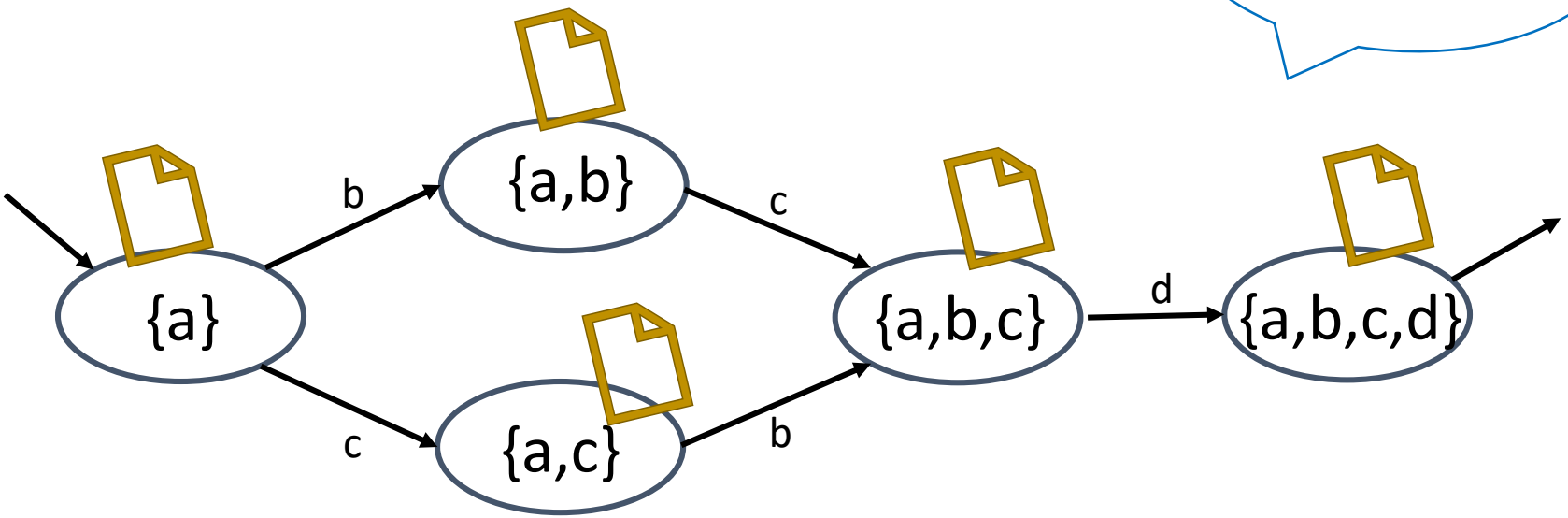
Annotated Finite State Machine

A-FSM



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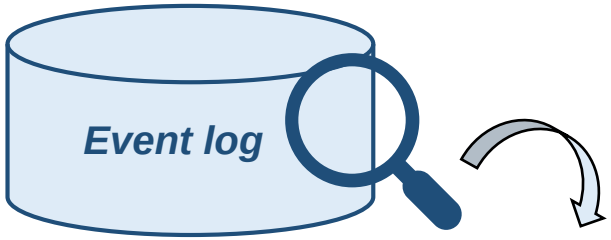

Case ID	Activity	Timestamp	Resource	Amount	Type	Income	Risk evaluation	Workload	Time period
12345	Application	*07.08.2015*	John	…	…	…	…	…	…
12467	Application	*03.11.2015*	John	…	…	…	…	…	…
12345	Waiting	*15.08.2015*	Mary	…	…	…	…	…	…
12345	Acceptation	*22.10.2015*	Mike	…	…	…	…	…	…
12467	Rejection	*24.11.2015*	Mike	…	…	…	…	…	…
12345	Payment	*12.01.2016*	Sarah	…	…	…	…	…	…

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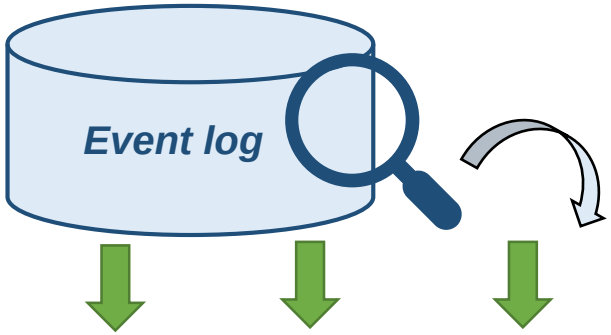

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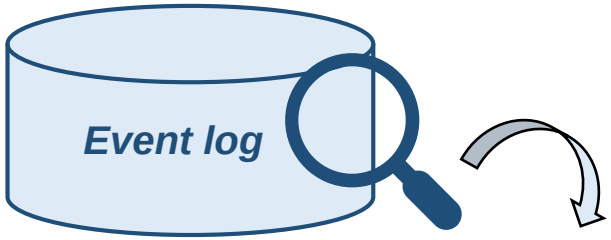

context

Case ID	Activity	Timestamp	Resource	Amount	Type	Income	Risk evaluation	Workload	Time period
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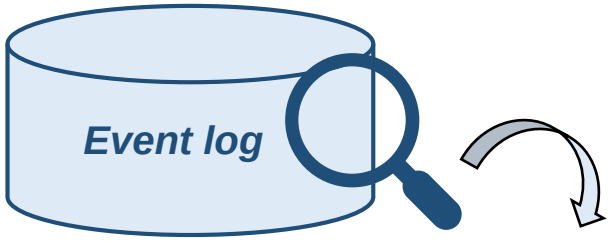

Case dependent features

External features

Case ID	Activity	Timestamp	Resource	Amount	Type	Income	Risk evaluation	Workload	Time period
12345	Application	*07.08.2015*	John	…	…	…	…	…	…
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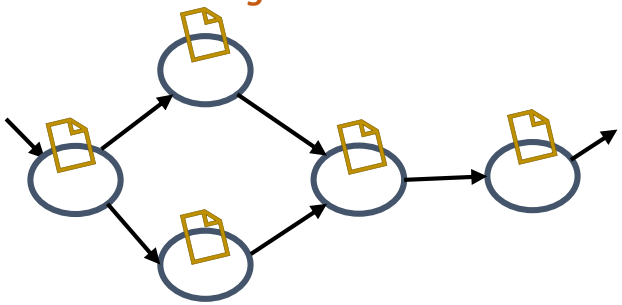
Approach - Idea

-Use context features to partition traces into clusters.

-Build A-FSM for each cluster.

Type = Standard AND Income = High



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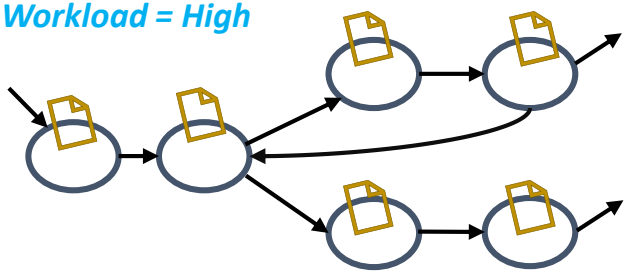
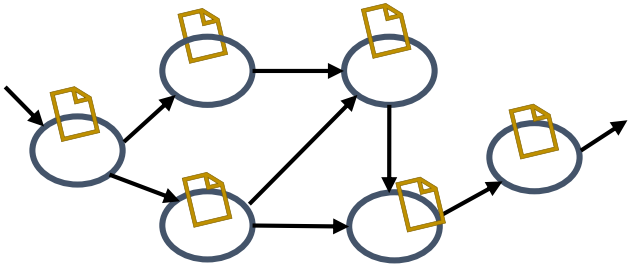


Risk = Low AND Time period = July



Approach - Idea

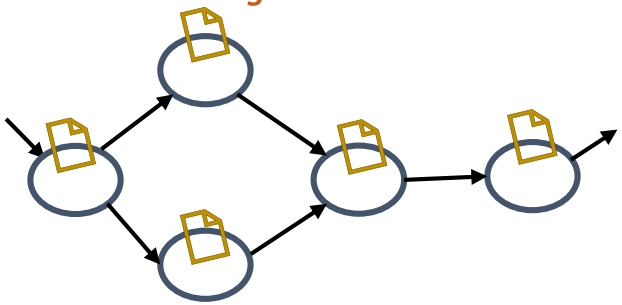
-Use context features to partition traces into clusters.

-Build A-FSM for each cluster.

New running case: <a,c,...>

Find corresponding cluster.

Type = Standard AND Income = High



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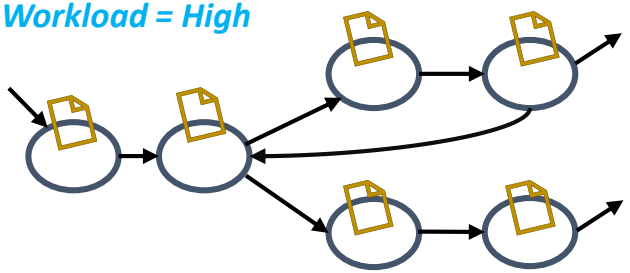

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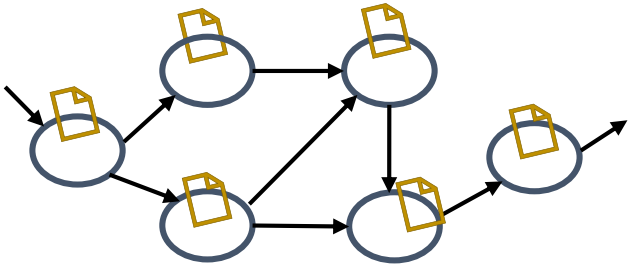

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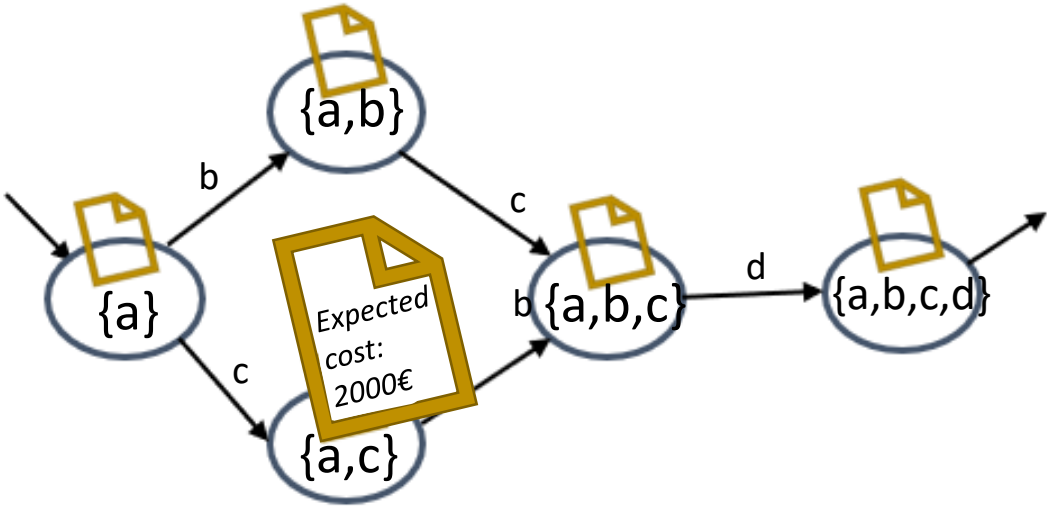

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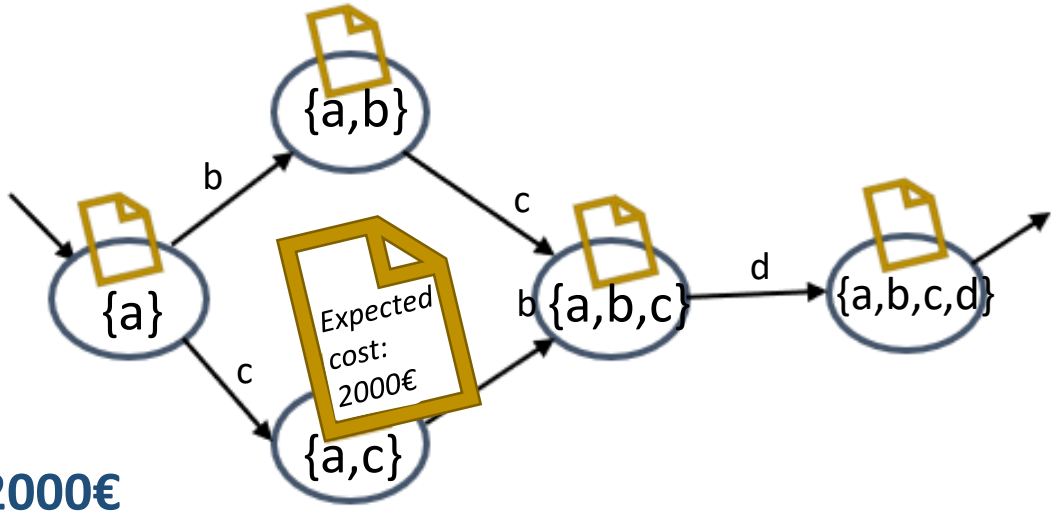
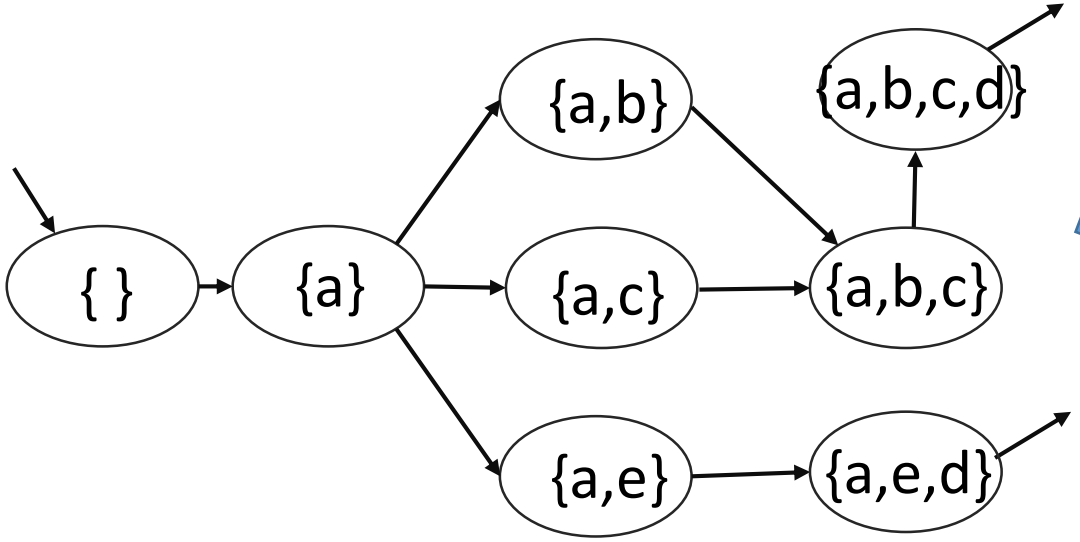
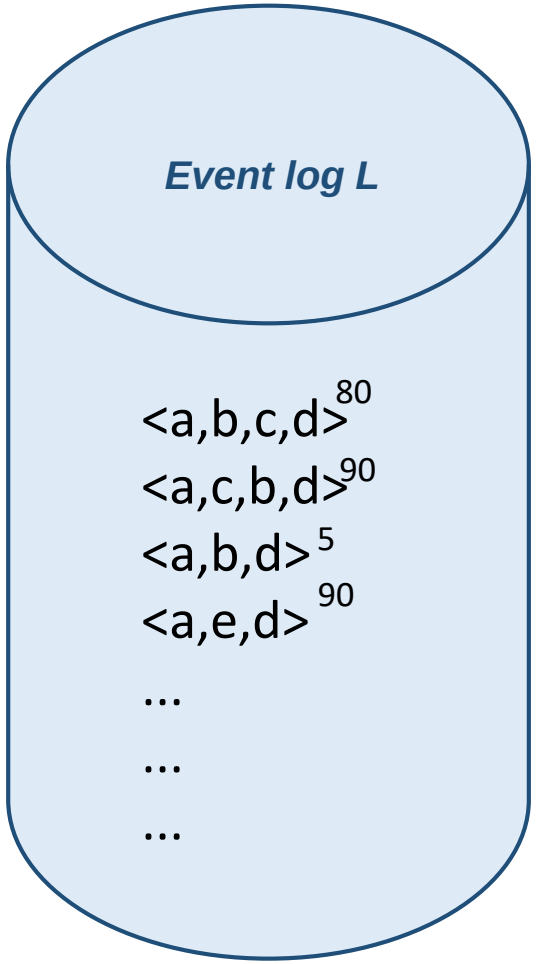


Predicted cost for this case: 2000€

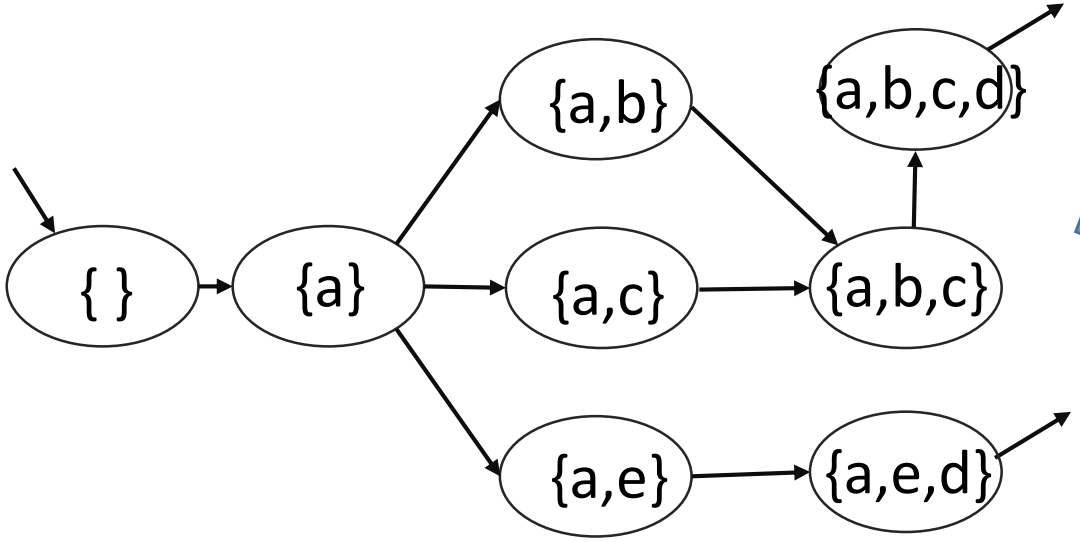
Transition Systems (for event logs)

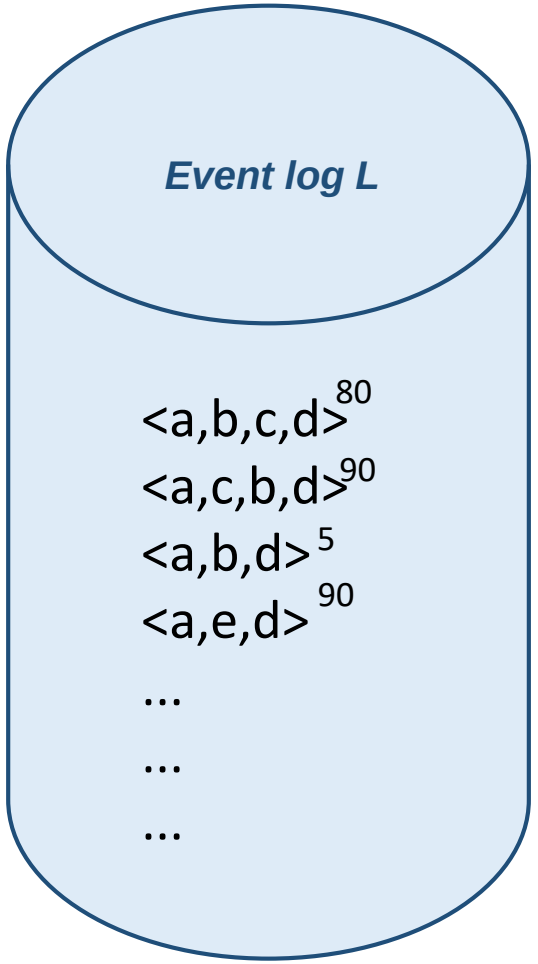




Transition Systems (for event logs)

The valid walks in the model correspond to traces in the log.





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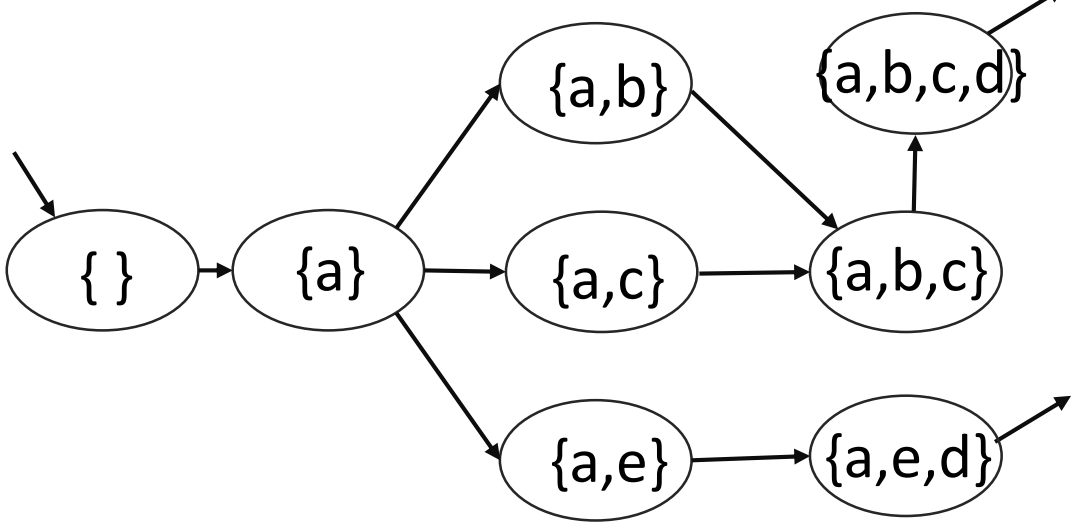


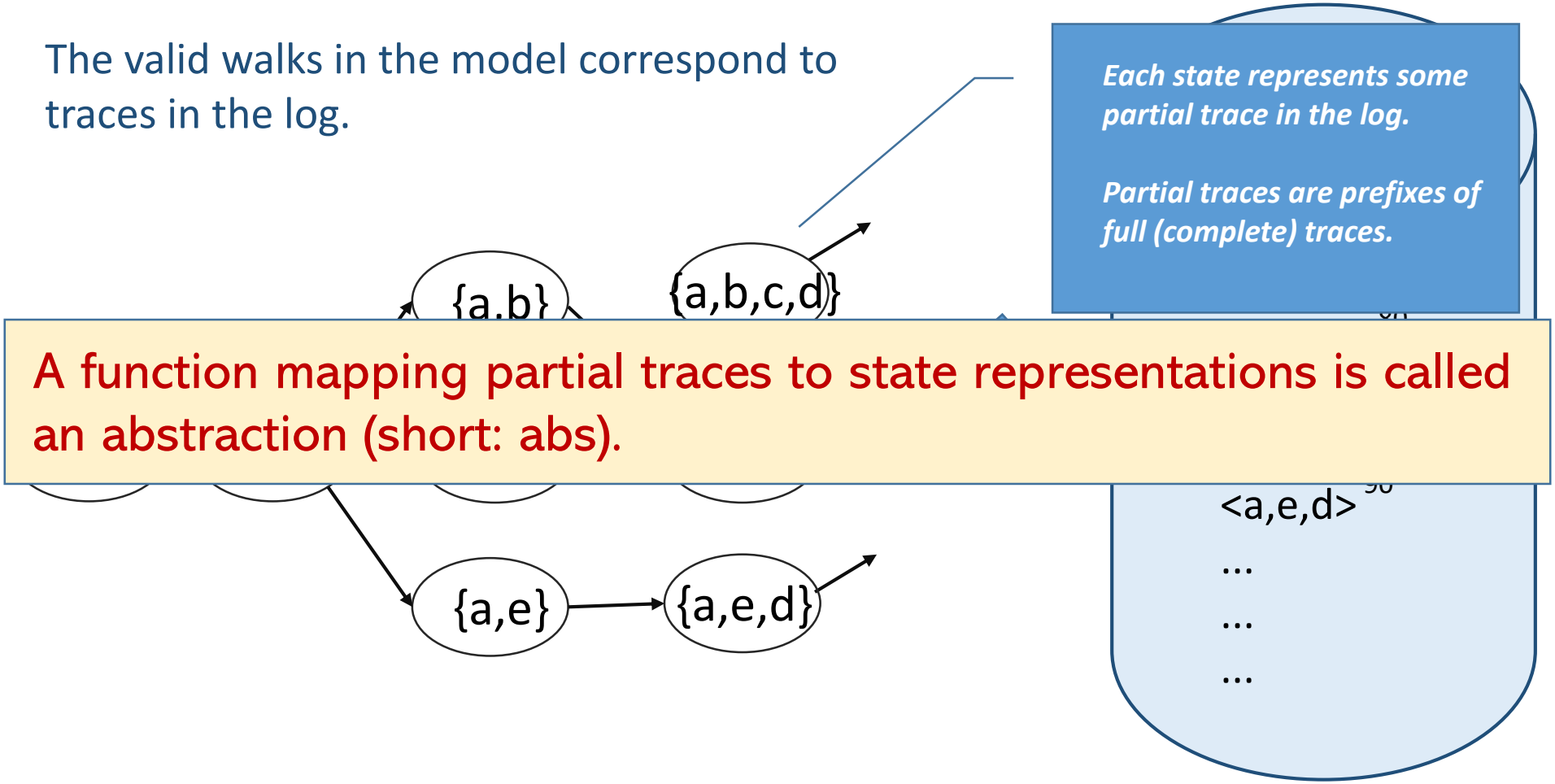
Each state represents some partial trace in the log.

Partial traces are prefixes of full (complete) traces.

<a,b,c,d>[80]
<a,c,b,d>[90]
<a,b,d>[5]
<a,e,d>[90]
...
...
...

Transition Systems (for event logs)

The valid walks in the model correspond to traces in the log.

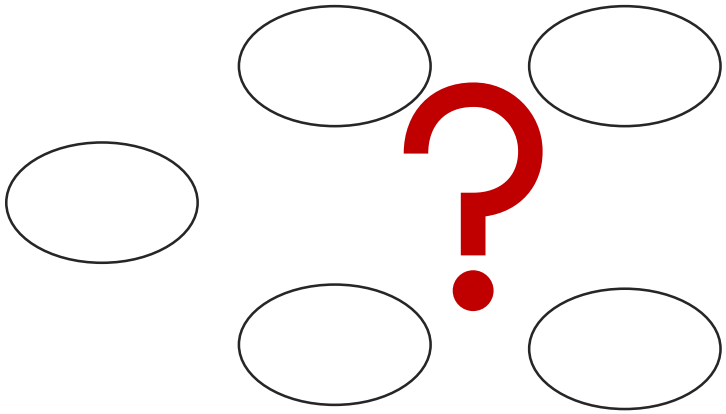


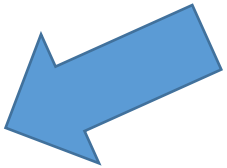
A function mapping partial traces to state representations is called an abstraction (short: abs).

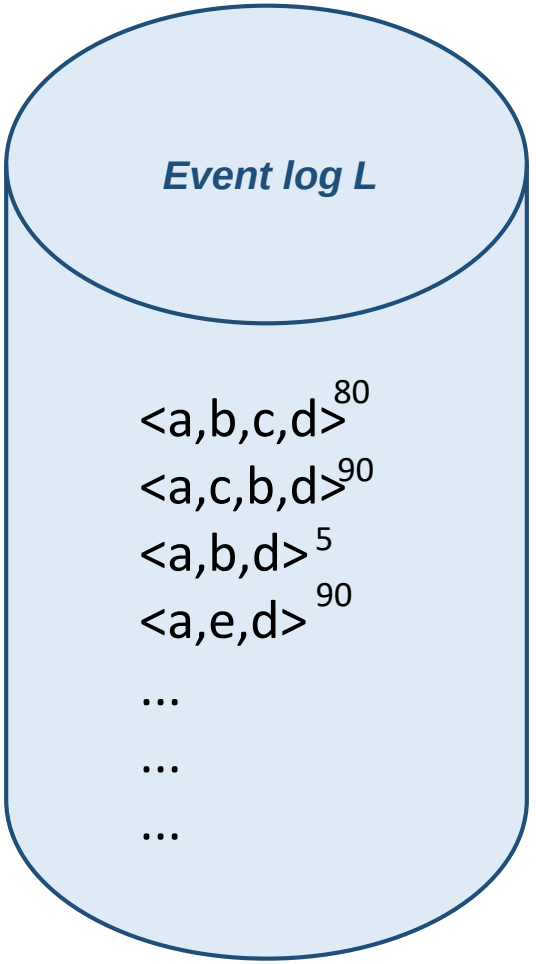
State representation function

Which state representations/which abs function?

-Sets
-Multisets
-Sequences
-Last k events
… ?







State representation function

Which state representations/which abs function?

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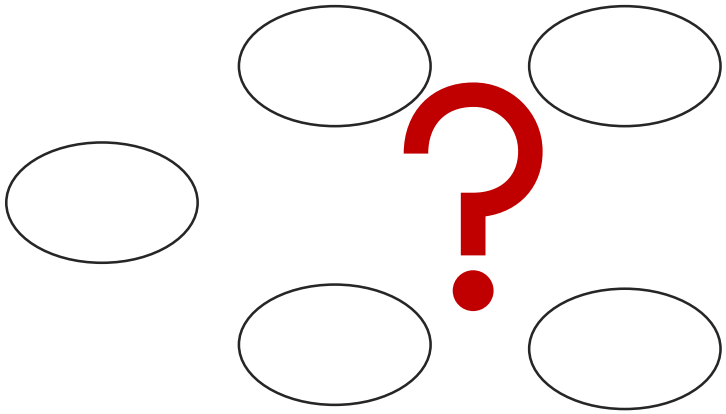
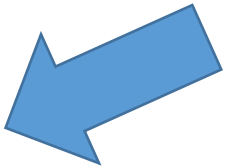
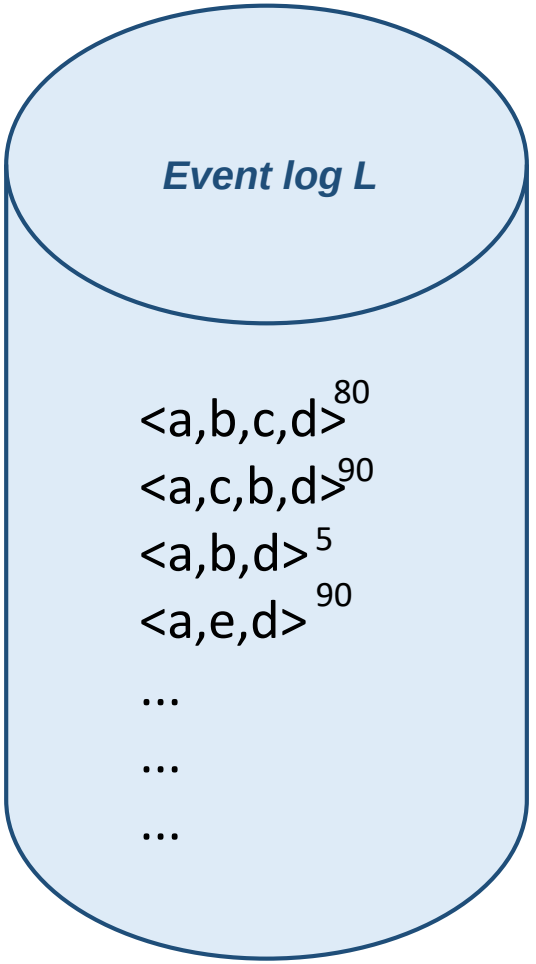
It depends on how we want to distinguish the traces regarding the prediction.







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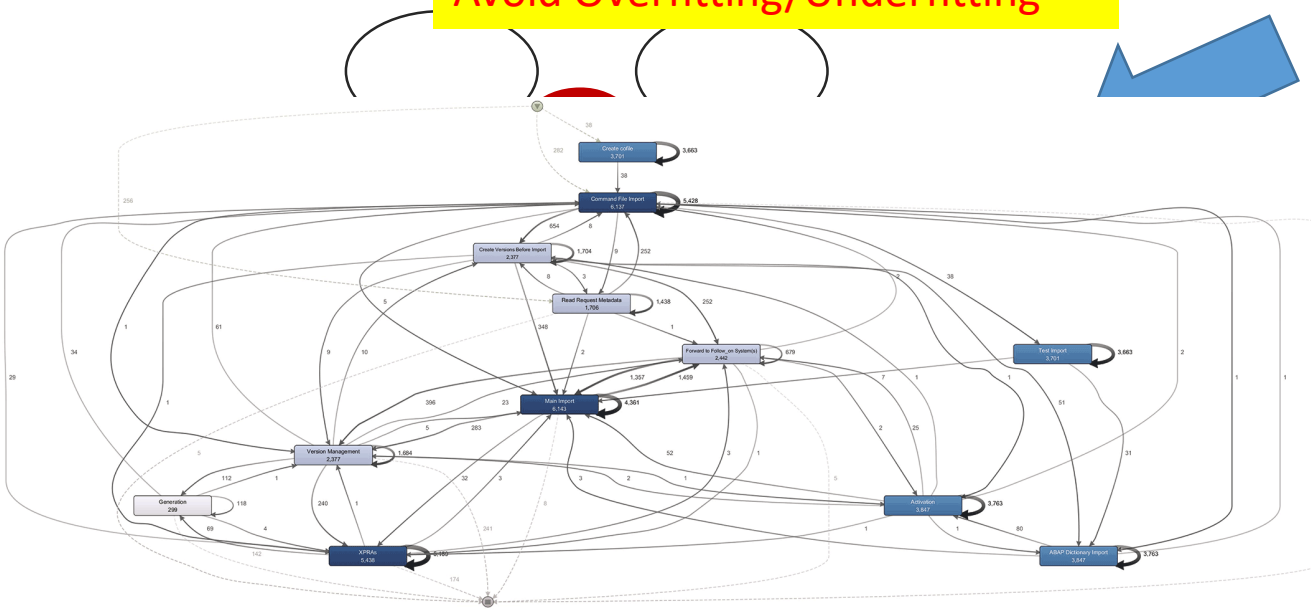
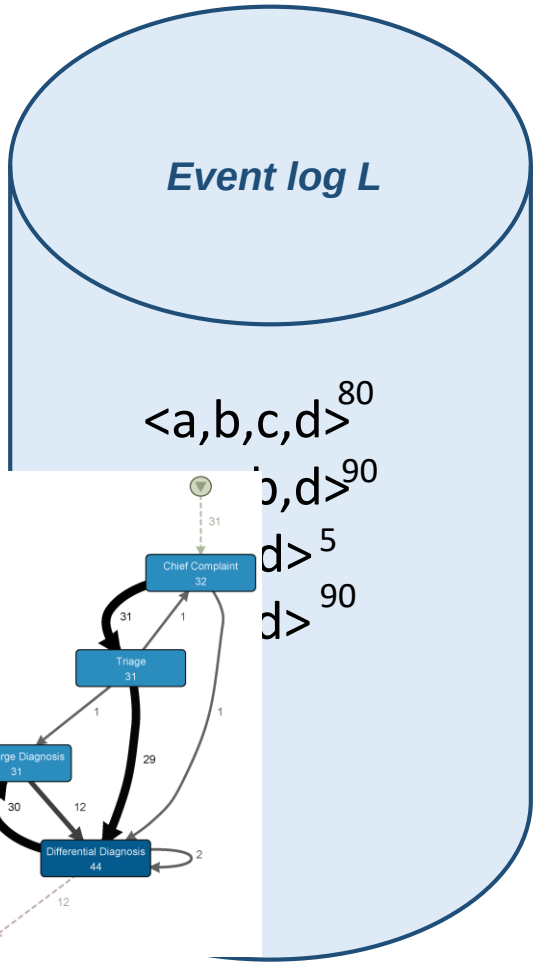
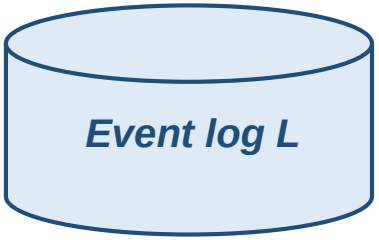
Avoid Overfitting/Underfitting





State representation function

abs: state representation functions

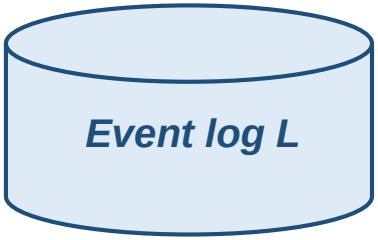


P(L): set of all prefix traces in log *L*.

abs: *P(L)* -> $\mathcal{R}$

State representation function

abs: state representation functions



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Set: order and number of occurrences of activities not important.

Bag (multiset): order of occurring activities not important.

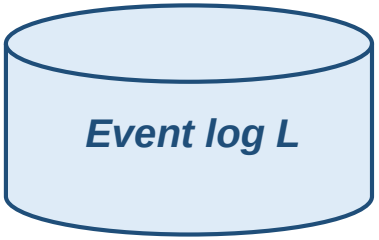
List (sequence): both order and number of occurrences of activities taken into consideration.

Maximal horizon: only last k activities relevant.

Filtering: ignore certain activities.

State representation function

abs: state representation functions



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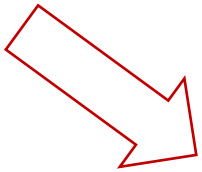
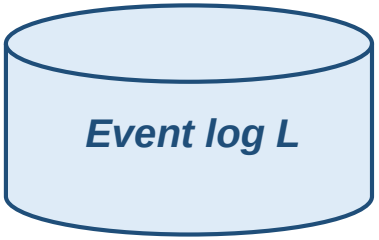


Only building blocks for more complex functions

State representation function

abs: state representation functions



P(L): set of all prefix traces in log *L*.

abs: *P(L)* -> $\mathcal{R}$

Consider:

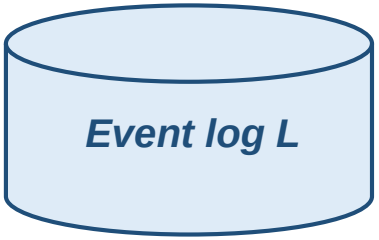
The number of occurrences of „*Waiting*“ in the last two months.

Filter partial trace based on timestamp, then compute the set abstraction.

Lack of resources in the last two months. Predict if case will be rejected.

State representation function

abs: state representation functions



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Consider:

The number of occurrences of „*Waiting*“ in the last two months.

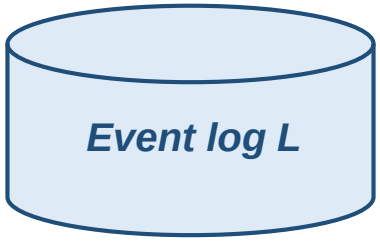
Filter partial trace based on timestamp, then compute the set abstraction.

The activities handled by „Mike“ out of the last 4 activities.

Set maximal horizon to 4, filter the partial trace based on its resource value, then use the multiset abstraction.

We want to predict duration of cases depending on the category of activities taken up by Mike.

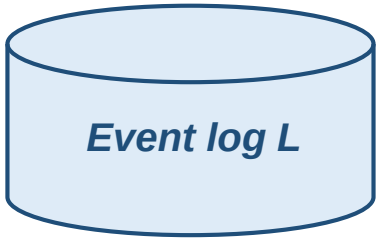
Transition Systems with Predictions



Case ID	Trace
1	<Application (00), Meeting (15), Waiting (20), Acceptation (62)>
2	<Application (15), Meeting (40), Waiting (45), Waiting (80), Rejection (95)>
3	<Meeting (48), Application (50), Waiting (60), Acceptation (85)>
4	<Meeting (80), Application (85), Waiting (90), Waiting (120), Rejection (130)>

activity timestamp

Transition Systems with Predictions



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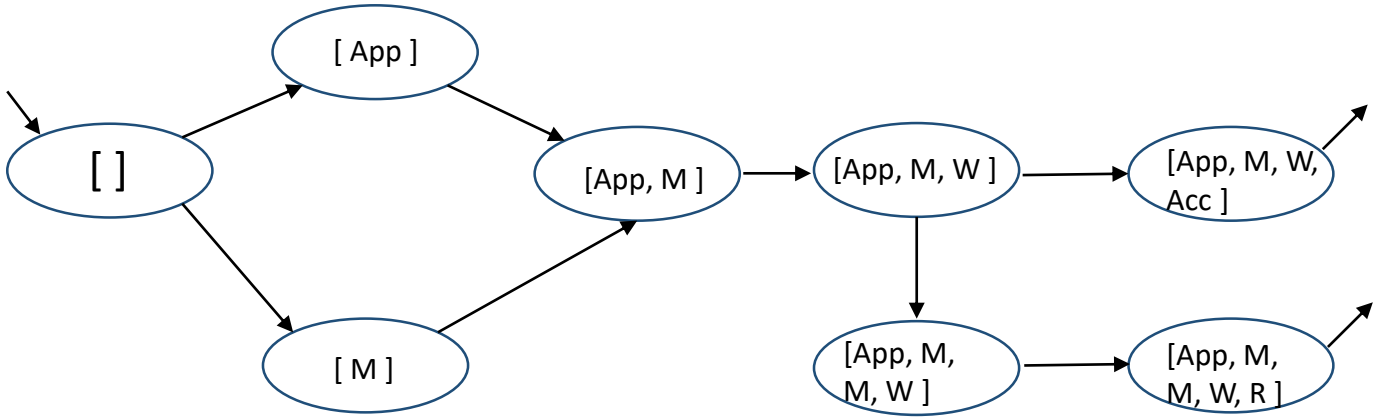
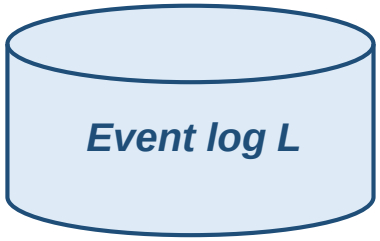
4	<**M**eeting (80), **App**lication (85), **W**aiting (90), **W**aiting (120), **R**ejection (130)>

activity **timestamp**

Use multiset abstraction:



Transition Systems with Predictions



Case ID	Trace
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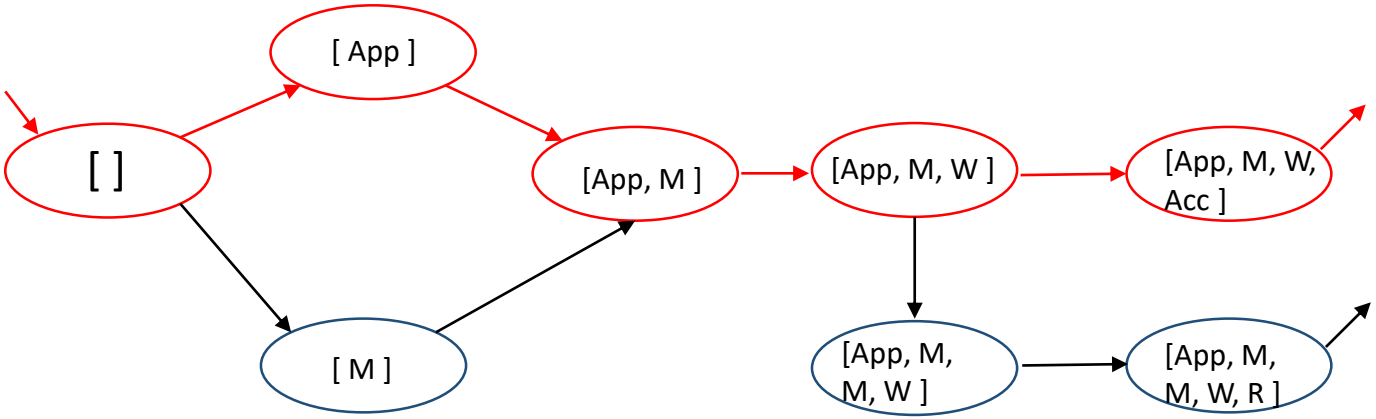

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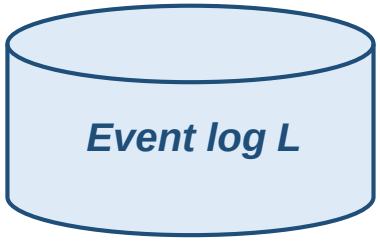

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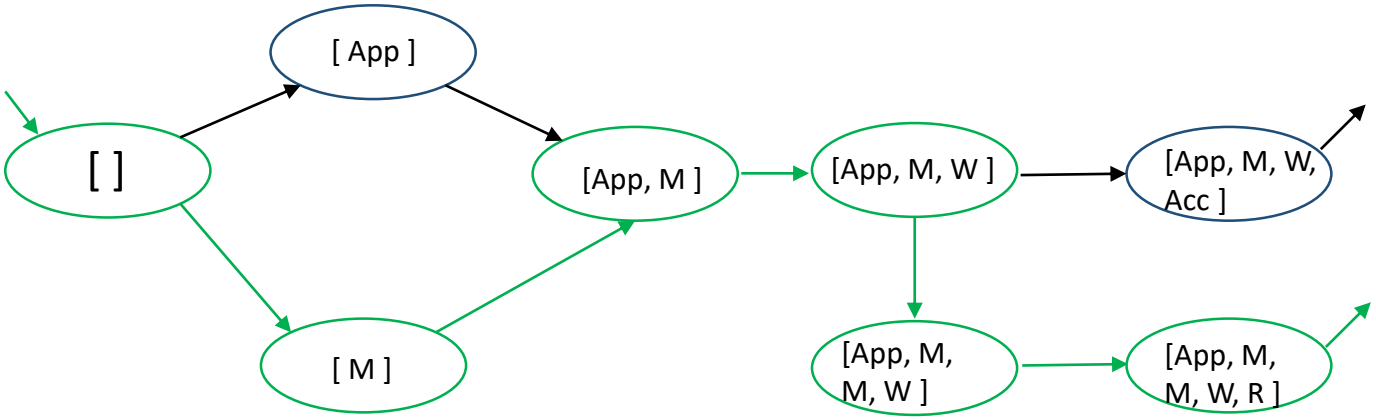
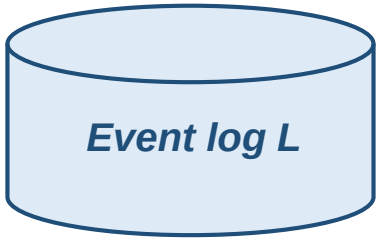


Transition Systems with Predictions



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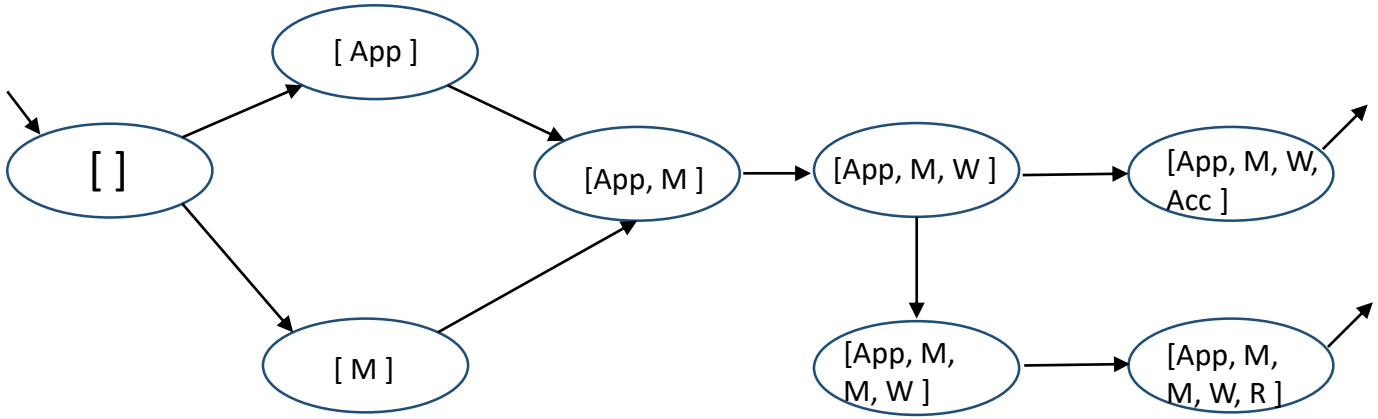
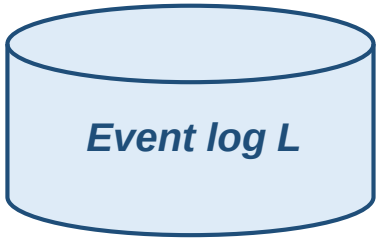


Predict remaining time until completion *RT*

Transition Systems with Predictions



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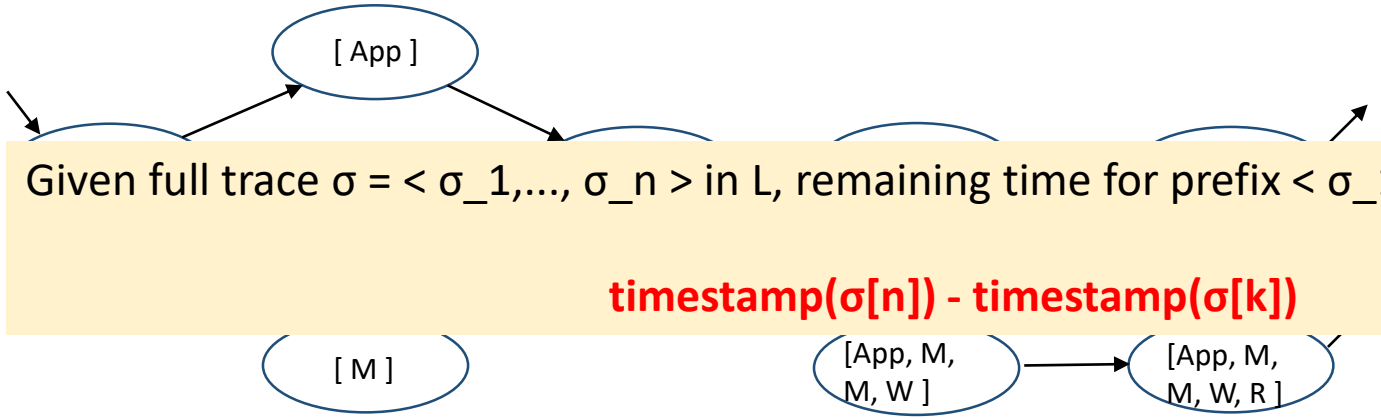
activity **timestamp**

Use multiset abstraction:

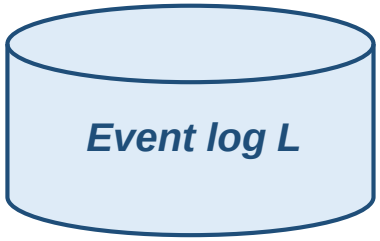
Predict remaining time until completion *RT*



Given full trace σ = < σ_1,..., σ_n > in L, remaining time for prefix < σ_1 ,..., σ _k> is:

timestamp(σ[n]) - timestamp(σ[k])

Transition Systems with Predictions



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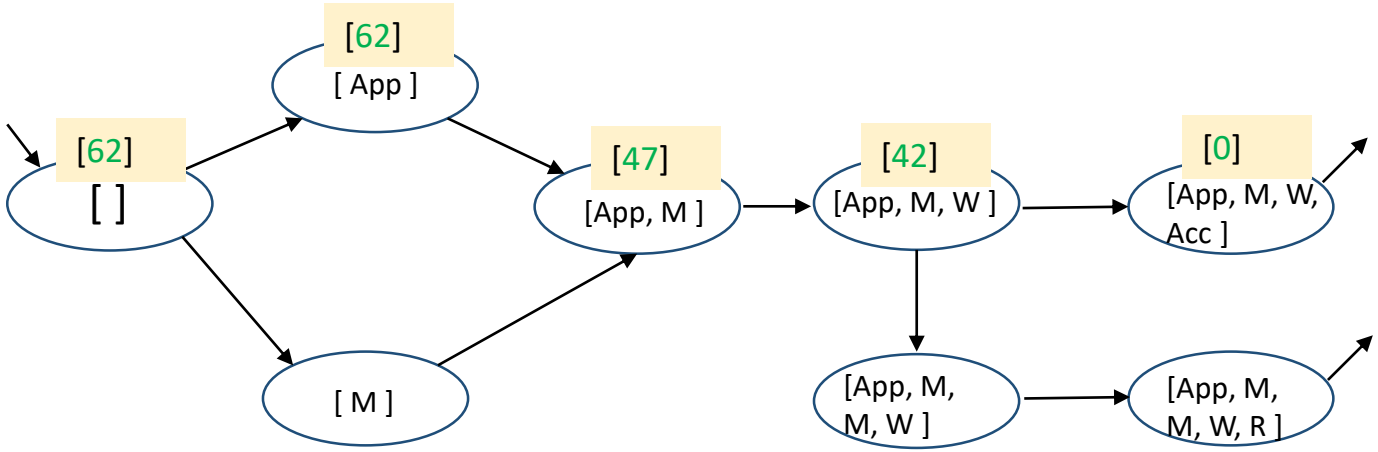
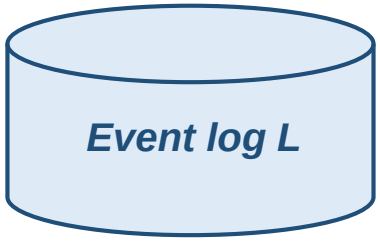
activity **timestamp**



Predict remaining time until completion *RT*

Transition Systems with Predictions



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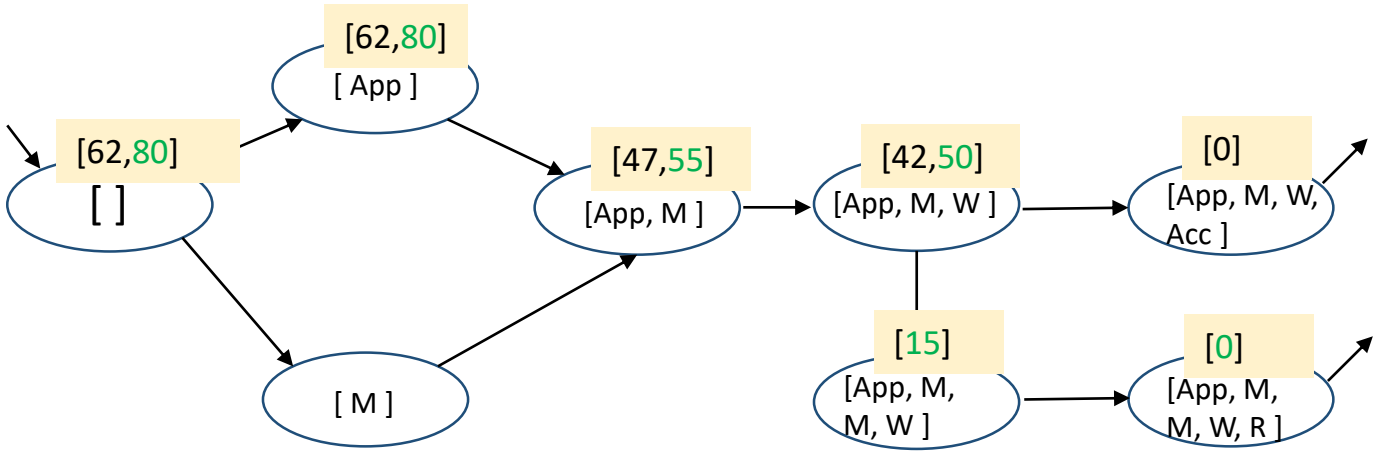
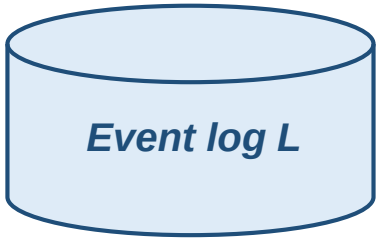
activity timestamp



Predict remaining time until completion *RT*

Transition Systems with Predictions



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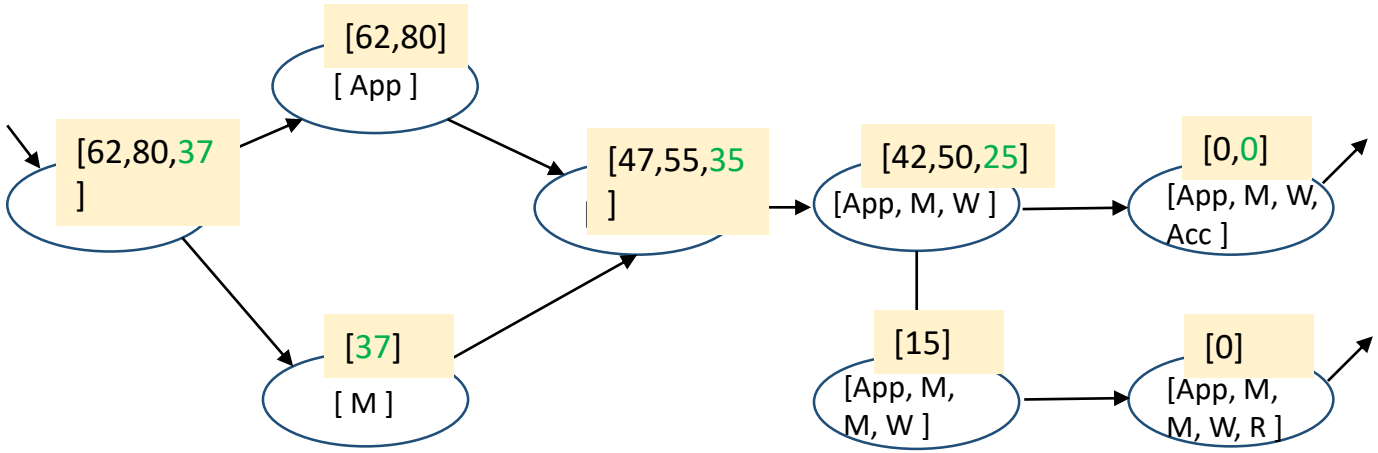
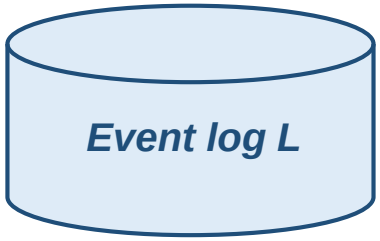
activity timestamp



Predict remaining time until completion *RT*

Transition Systems with Predictions



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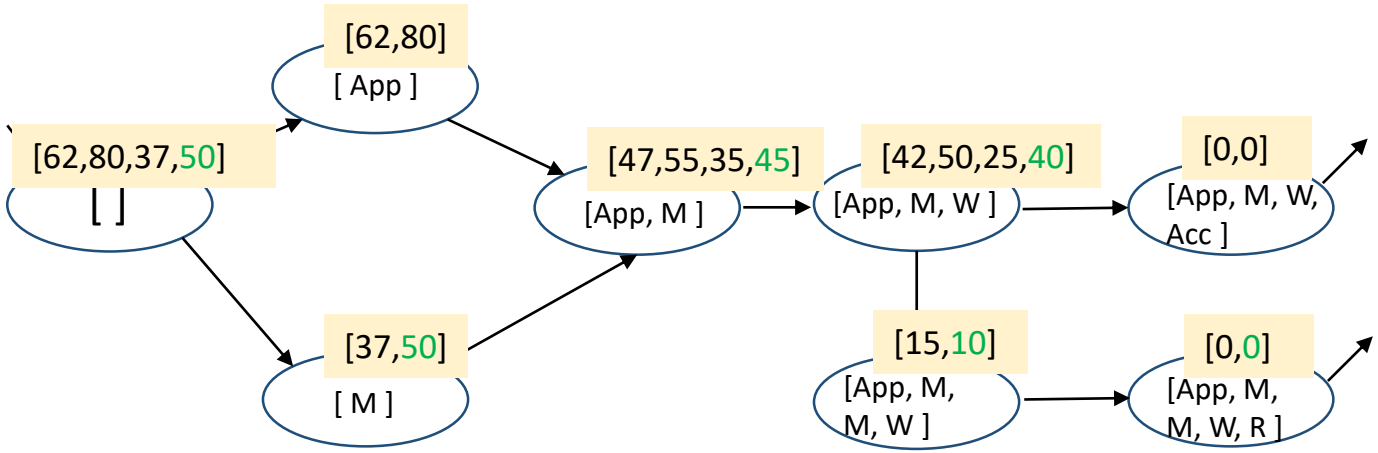
activity **timestamp**



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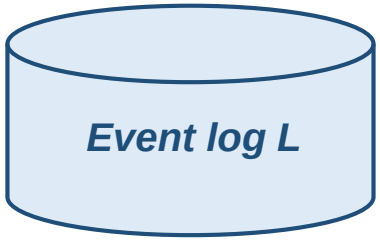
Transition Systems with Predictions



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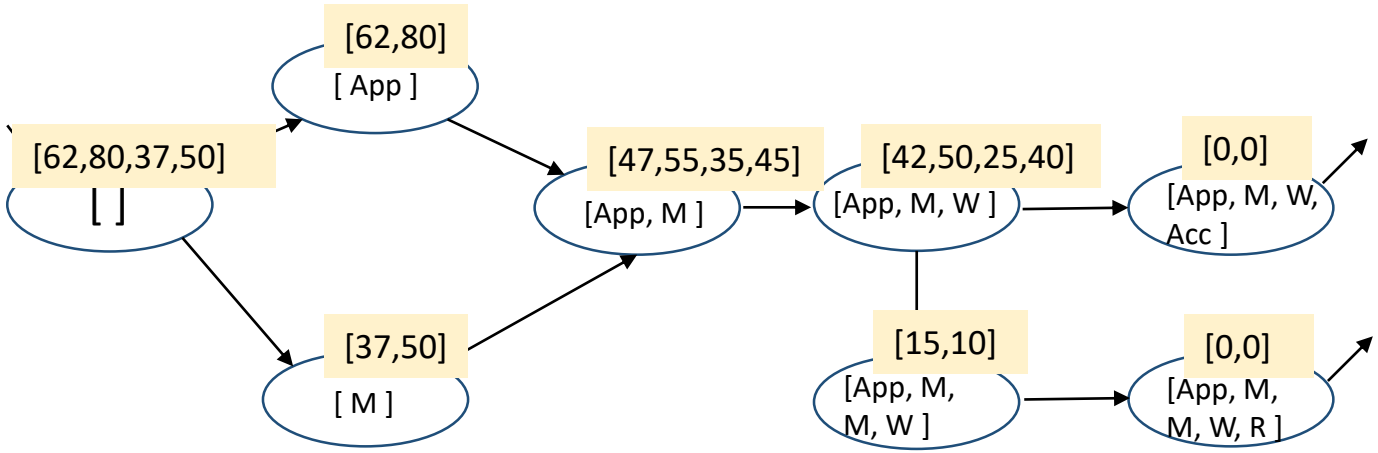
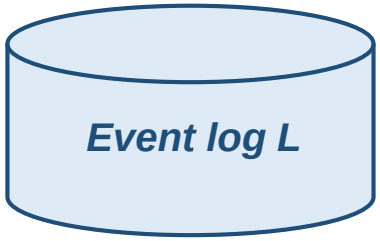
activity timestamp



Predict remaining time until completion *RT*

Take the average of remaining times

Transition Systems with Predictions



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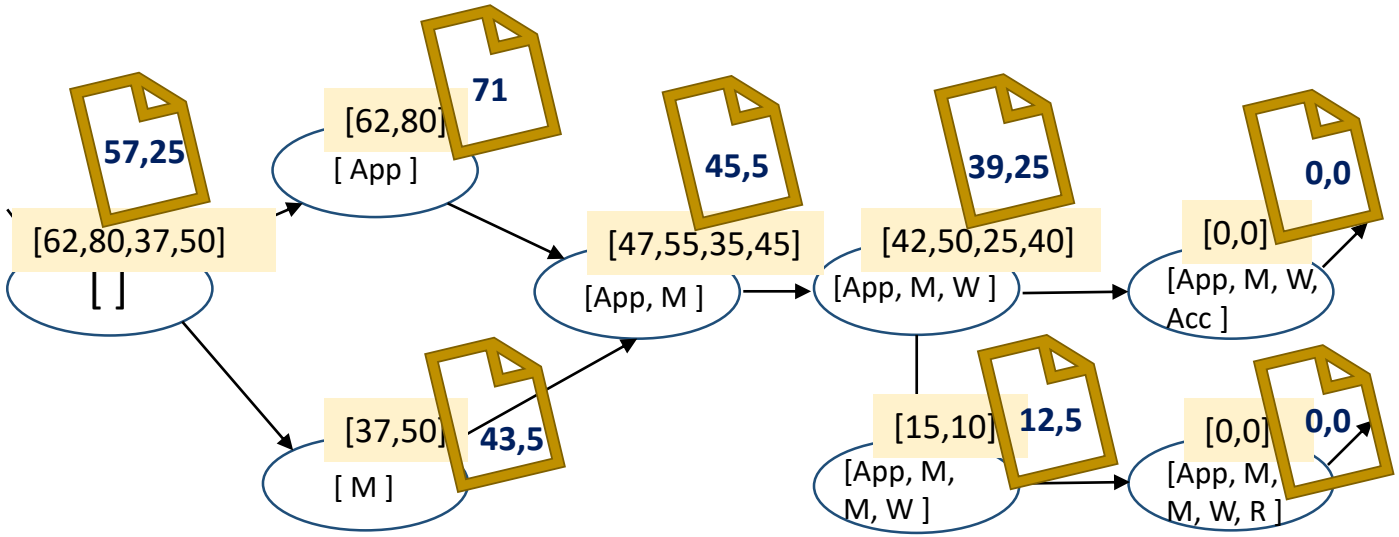


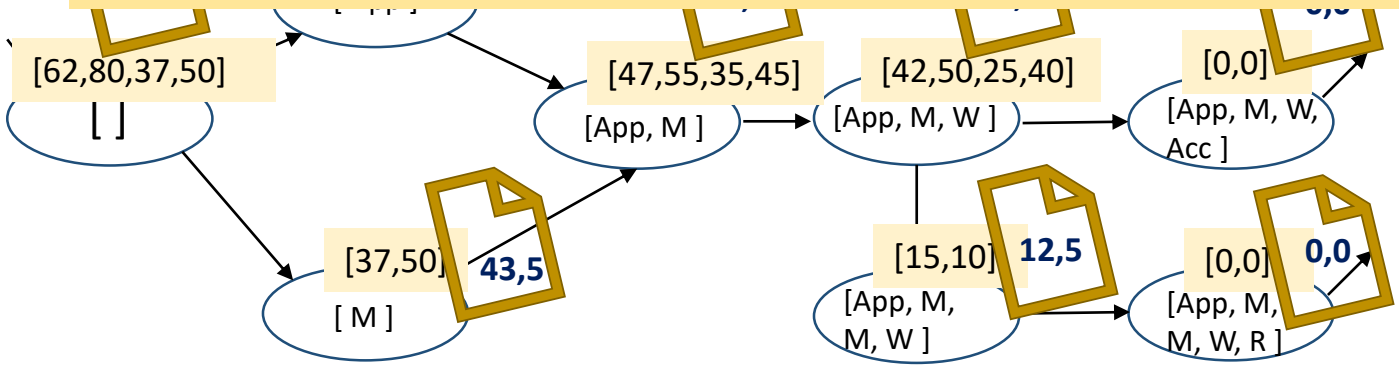
Predict remaining time until completion *RT*

Take the average of remaining times

Transition Systems with Predictions

Other predictions:

- expected cost of the trace
- whether some particular activity has taken place
- whether some resource will be involved
- …



Take the average of remaining times

Prediction model μ

Compute a prediction for the universe of traces…

$$\mu: \mathcal{T} \rightarrow \mathcal{M}$$

universe of traces

range of predicted values

Prediction model μ

Compute a prediction for the universe of traces…

$$\mu: \mathcal{T} \rightarrow \mathcal{M}$$

universe of traces

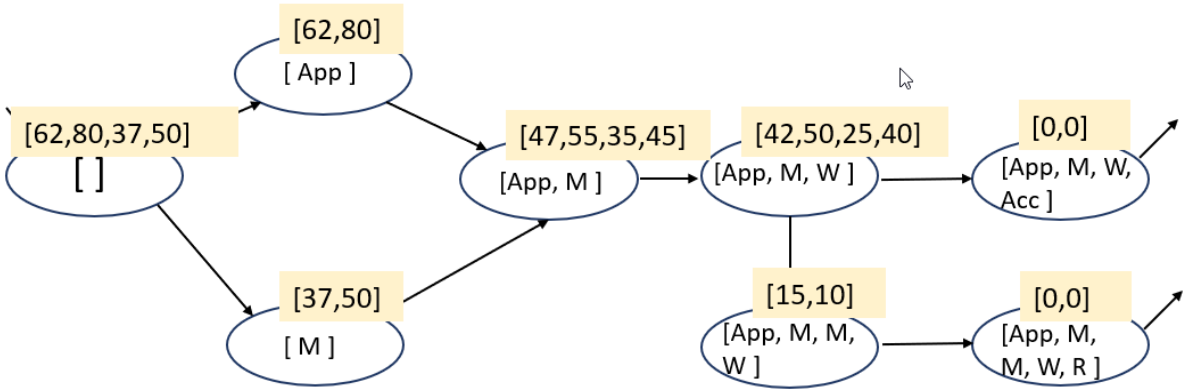
range of predicted values

…using the log L as training set with known prediction values over the set of prefixes.

$$\hat{\mu}: P(L) \rightarrow \mathcal{M}$$

Where *context* comes into play..

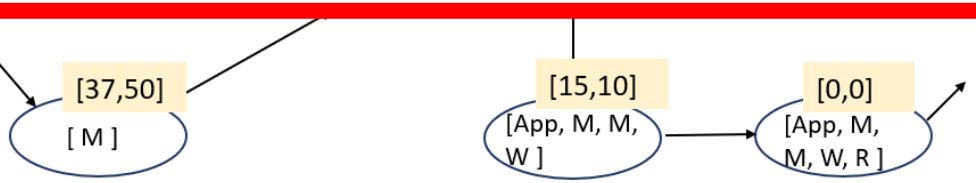
*Only one **A-FSM** for the log*



Where *context* comes into play..

*Only one **A-FSM** for the log*

But processes may be very complex and flexible!



Where *context* comes into play..

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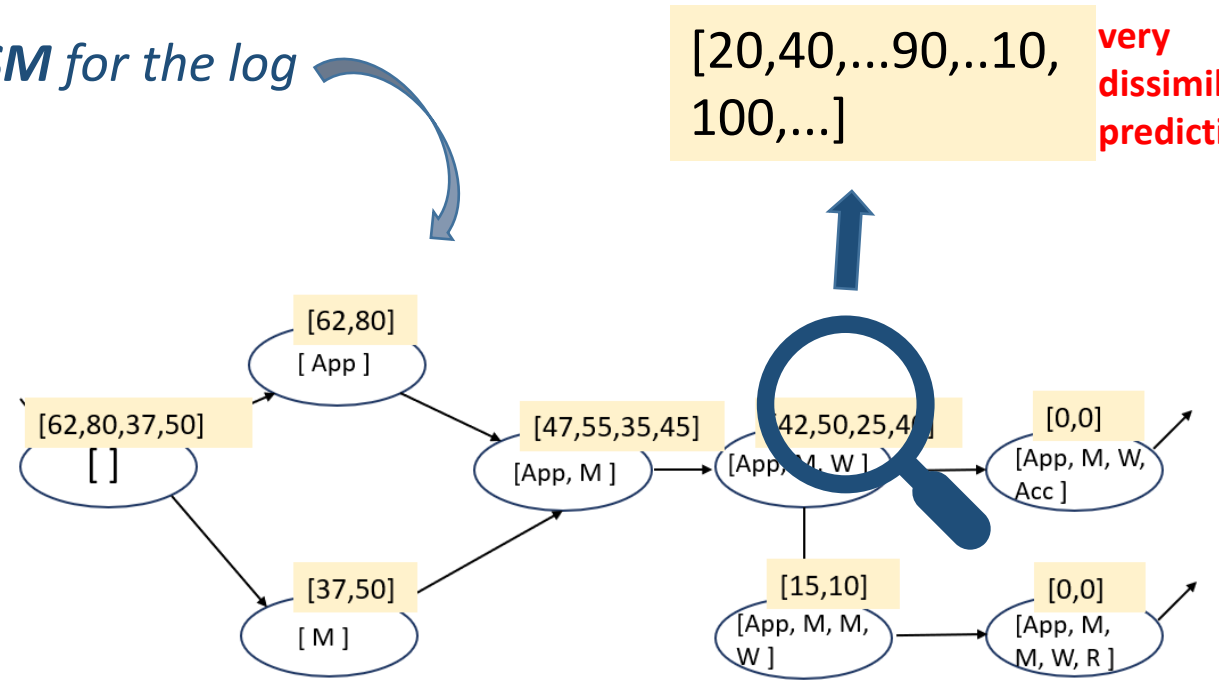


Where *context* comes into play..

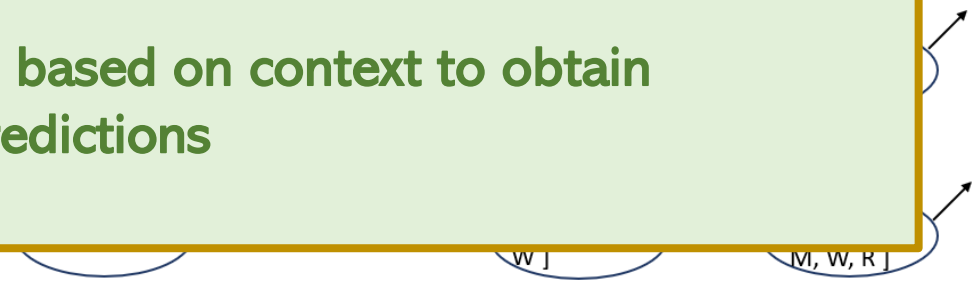
*Only one **A-FSM** for the log*

[20,40,...90,..10, 100,...]

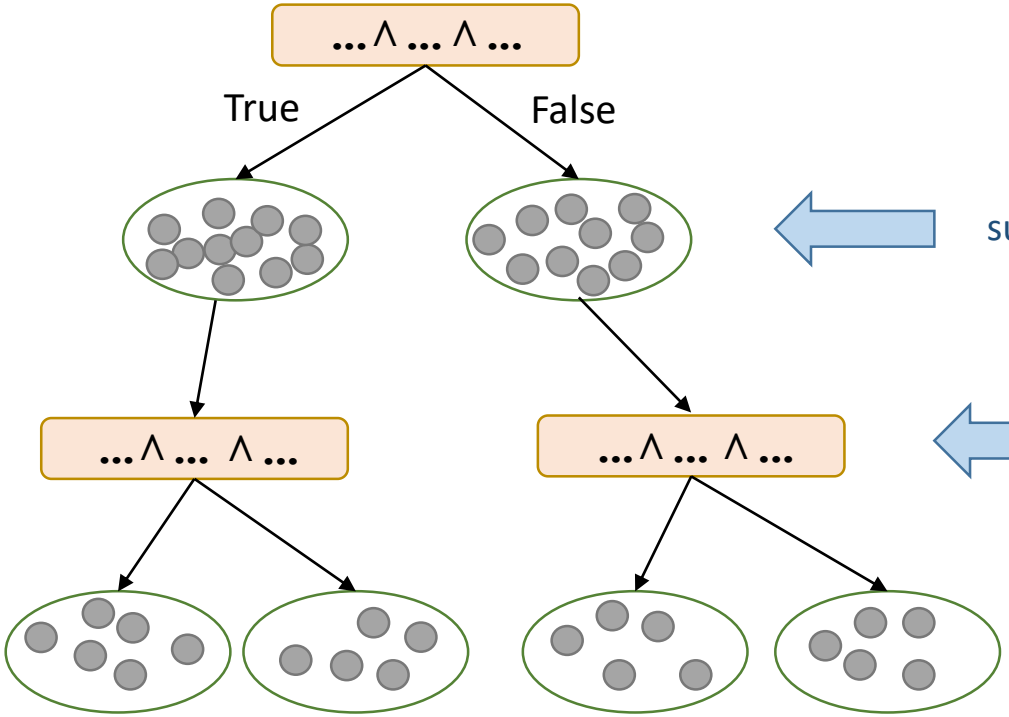
very dissimilar predictions!

Reason: values of *context* features

Idea: partition traces based on context to obtain more *precise* predictions



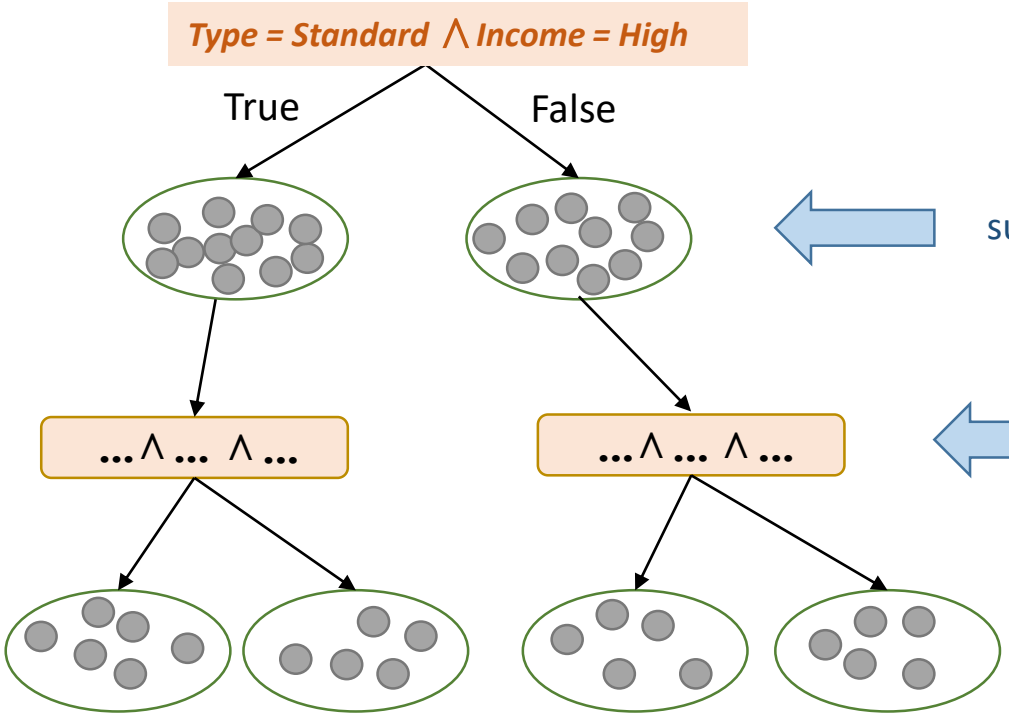
Predictive Clustering Trees (PCT)



subset of full traces

logical claim(s) made on (some) context values

Predictive Clustering Trees (PCT)



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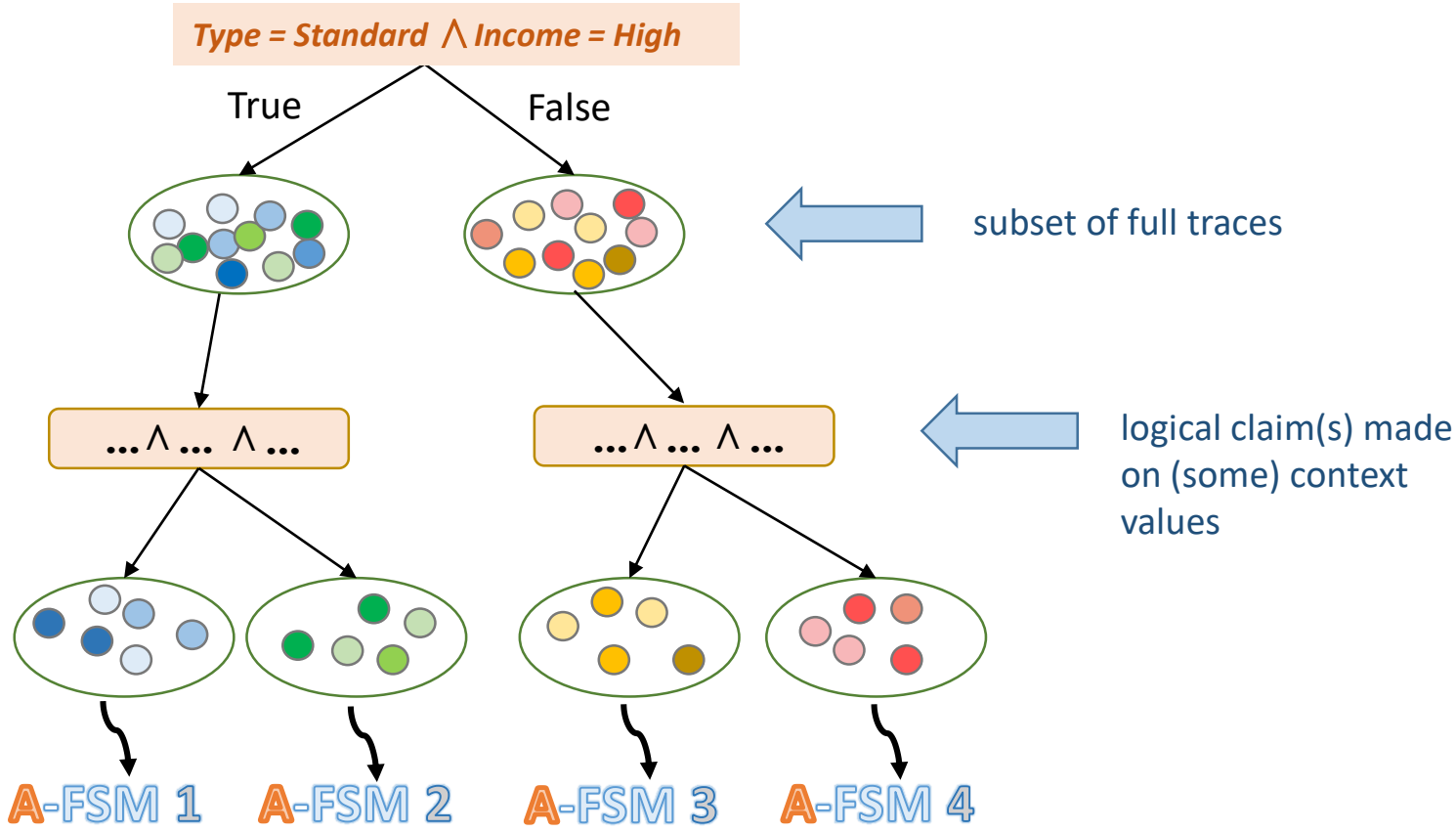

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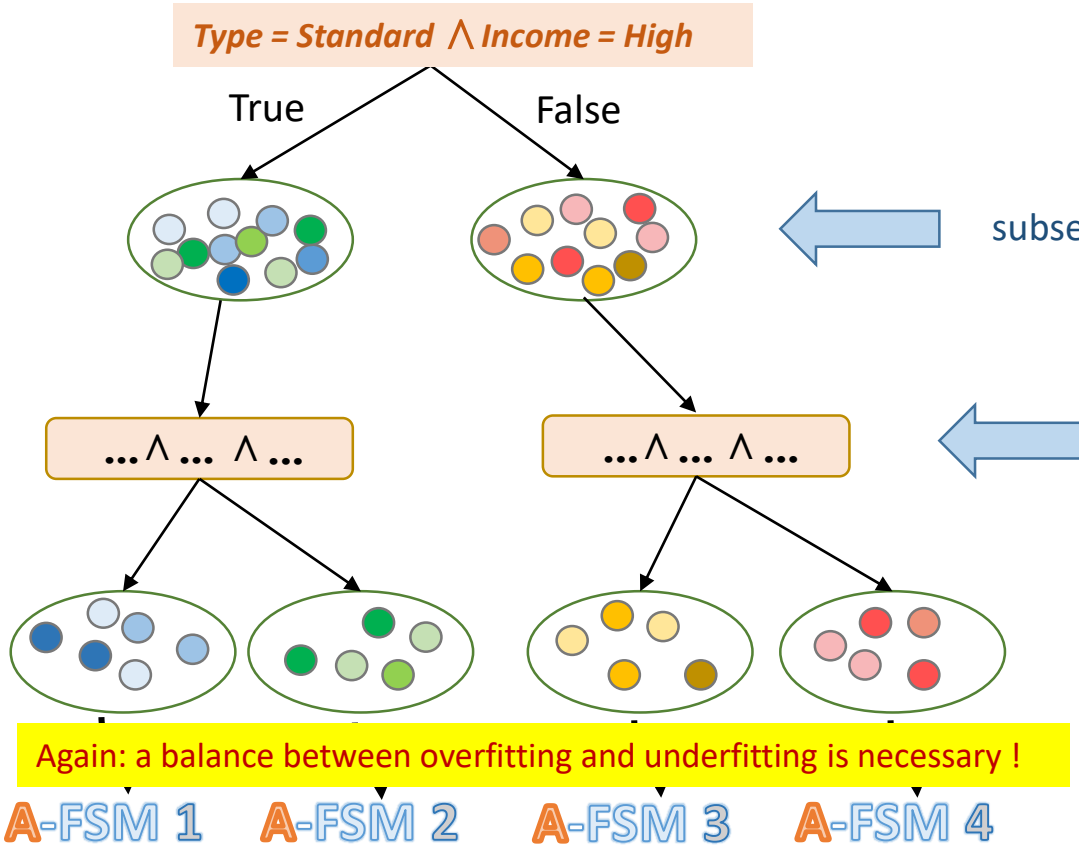

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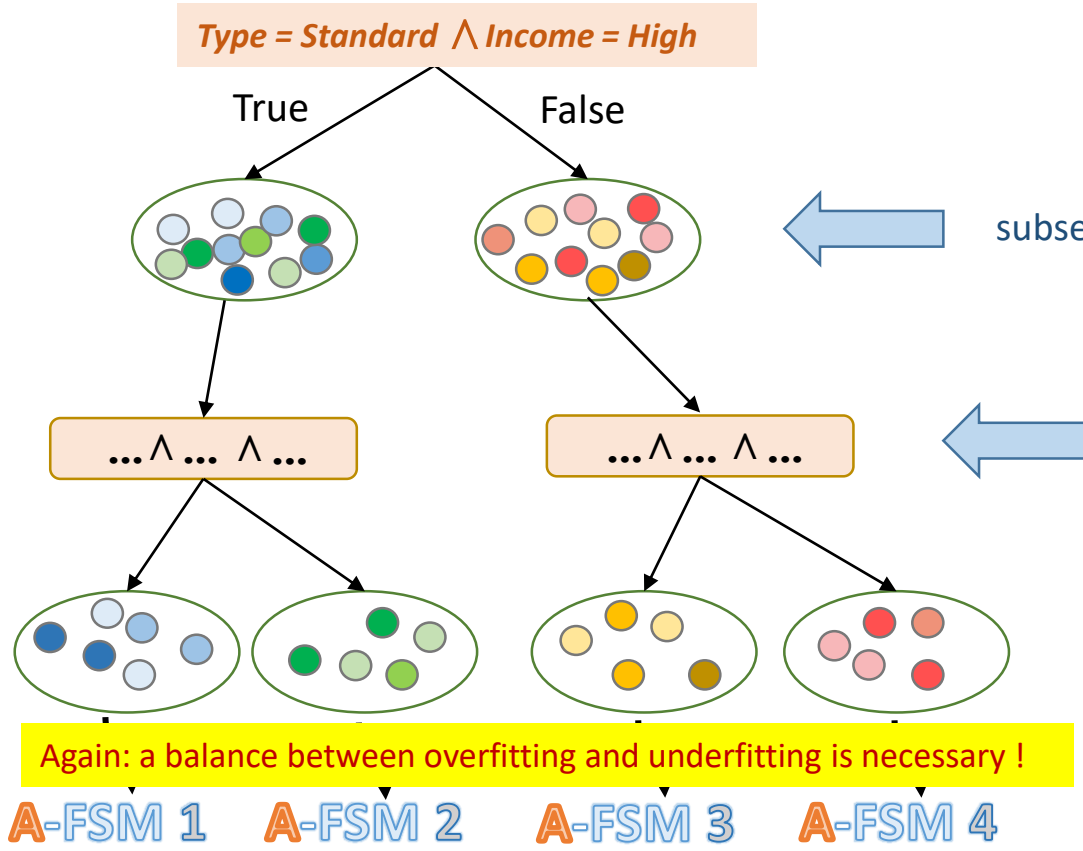
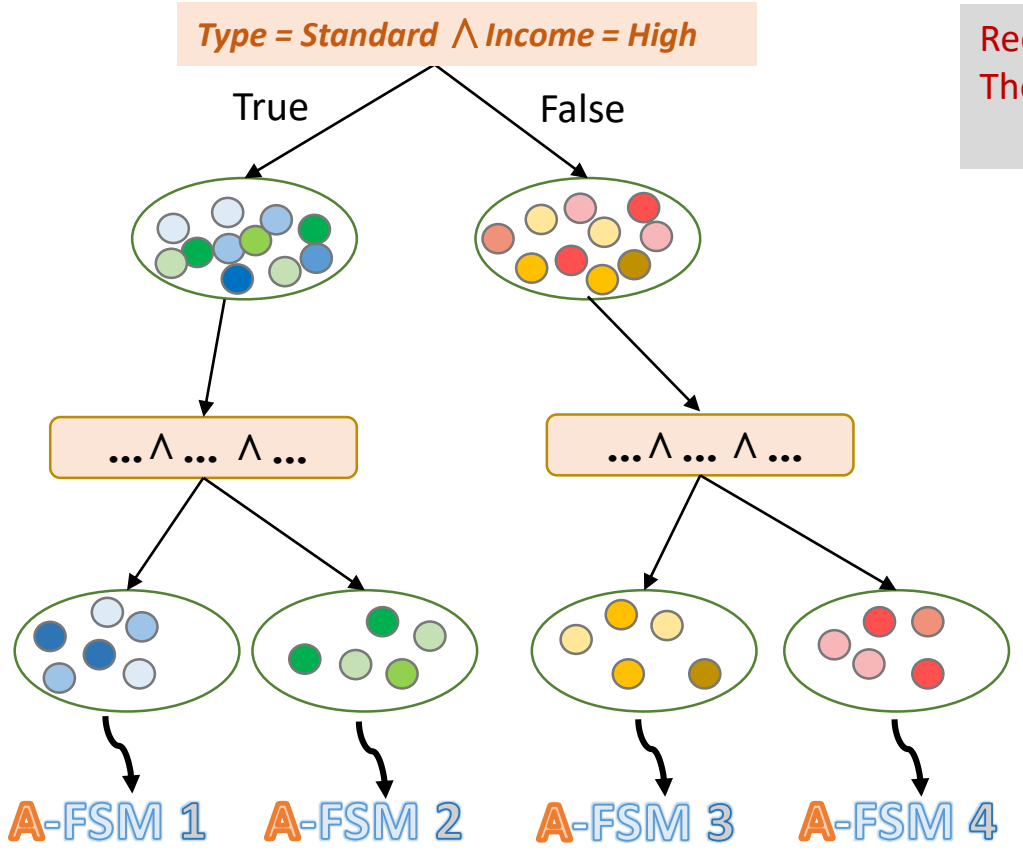


subset of full traces

logical claim(s) made on (some) context values

How are the traces represented?

Predictive Clustering Trees (PCT)



Recall:
The predictions in the states should be similar!

Similar traces:

- the set of states their prefixes are mapped to share many common elements

- the prediction values they assign to these states are similar

Vector representation for clustering

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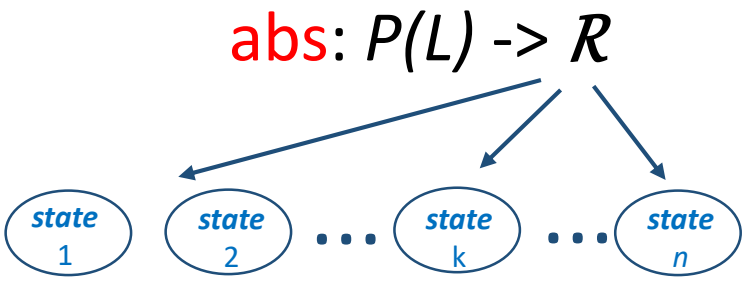
Vector representation for clustering



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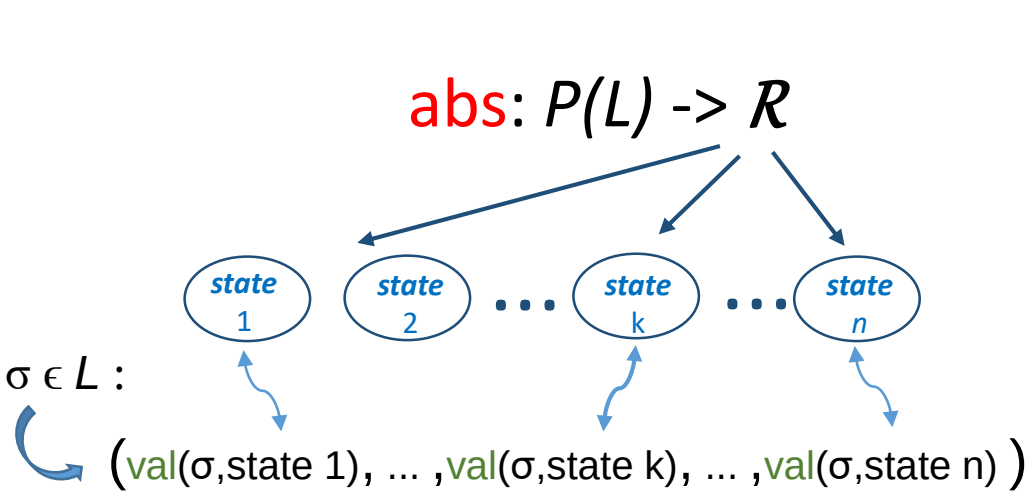

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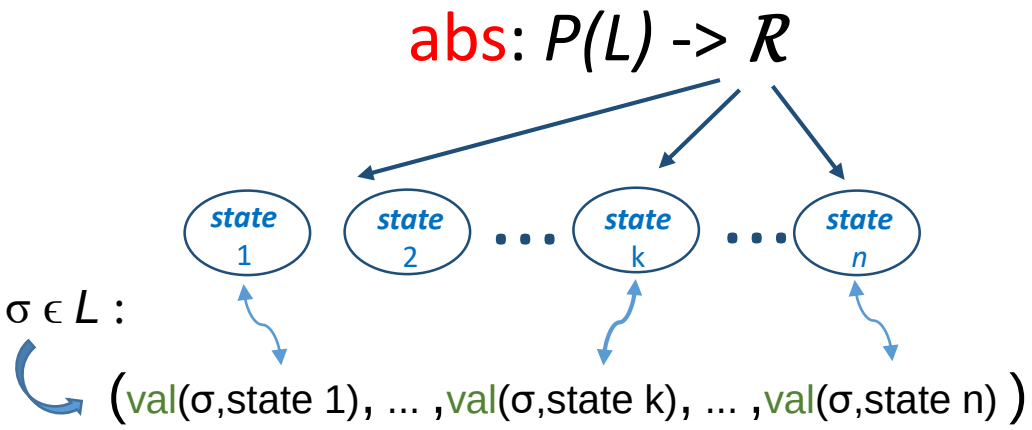

$$val(\sigma, s) = \begin{cases} \text{NULL} & \text{if no prefix of } \sigma \text{ is mapped to } s; \\ agg(\{\hat{\mu}(\text{prefix}_1), ..., \hat{\mu}(\text{prefix}_m)\}) & \text{otherwise,} \end{cases}$$

where $\{\text{prefix}_1, ..., \text{prefix}_m\} = \{\text{prefix of } \sigma \mid abs(\text{prefix}) = s\}$

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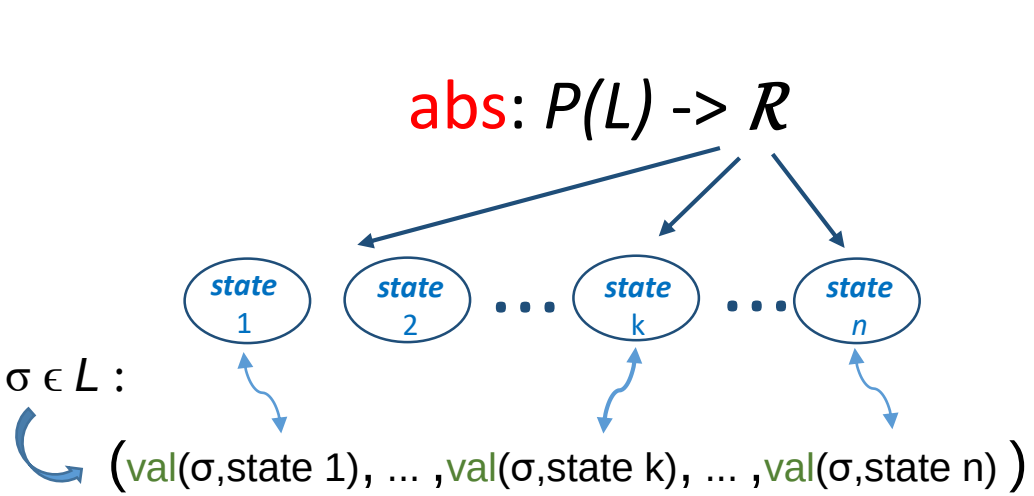

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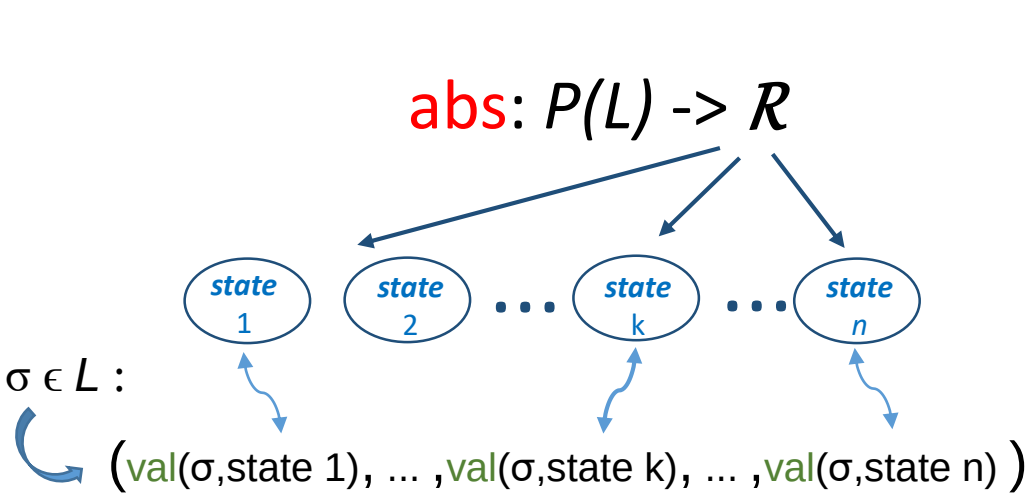
- the prediction values they assign to these states are similar

Vector representation for clustering



$$val(\sigma, s) = \begin{cases} \text{NULL} & \text{if no prefix of } \sigma \text{ is mapped to } s; \\ agg(\{\hat{\mu}(\text{prefix}_1), ..., \hat{\mu}(\text{prefix}_m)\}) & \text{otherwise,} \end{cases}$$

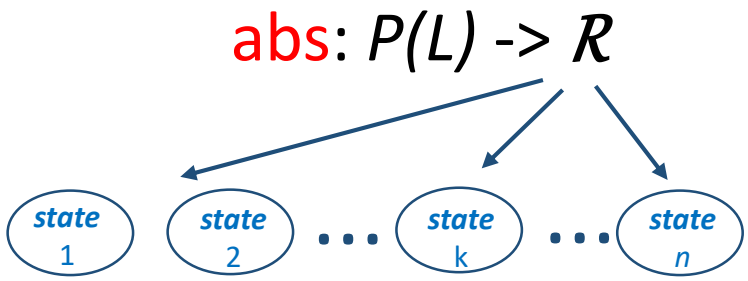
where $\{\text{prefix}_1, ..., \text{prefix}_m\} = \{\text{prefix of } \sigma \mid abs(\text{prefix}) = s\}$

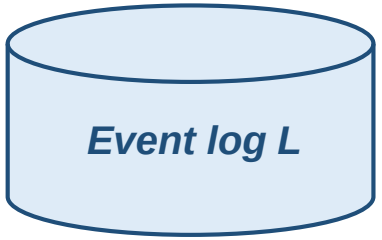
Similar traces:

- the set of states their prefixes are mapped to share many common elements

- the prediction values they assign to these states are similar

Using all states – Overfitting?

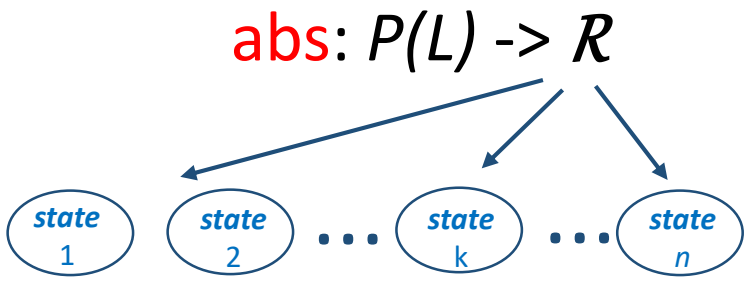


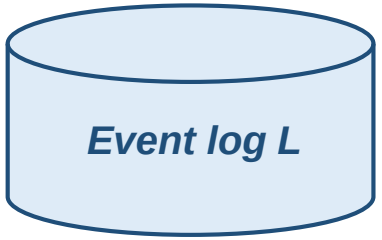


$\sigma \in L$:

(val(σ,state 1), ... ,val(σ,state k), ... ,val(σ,state n))

Using all states – Overfitting?





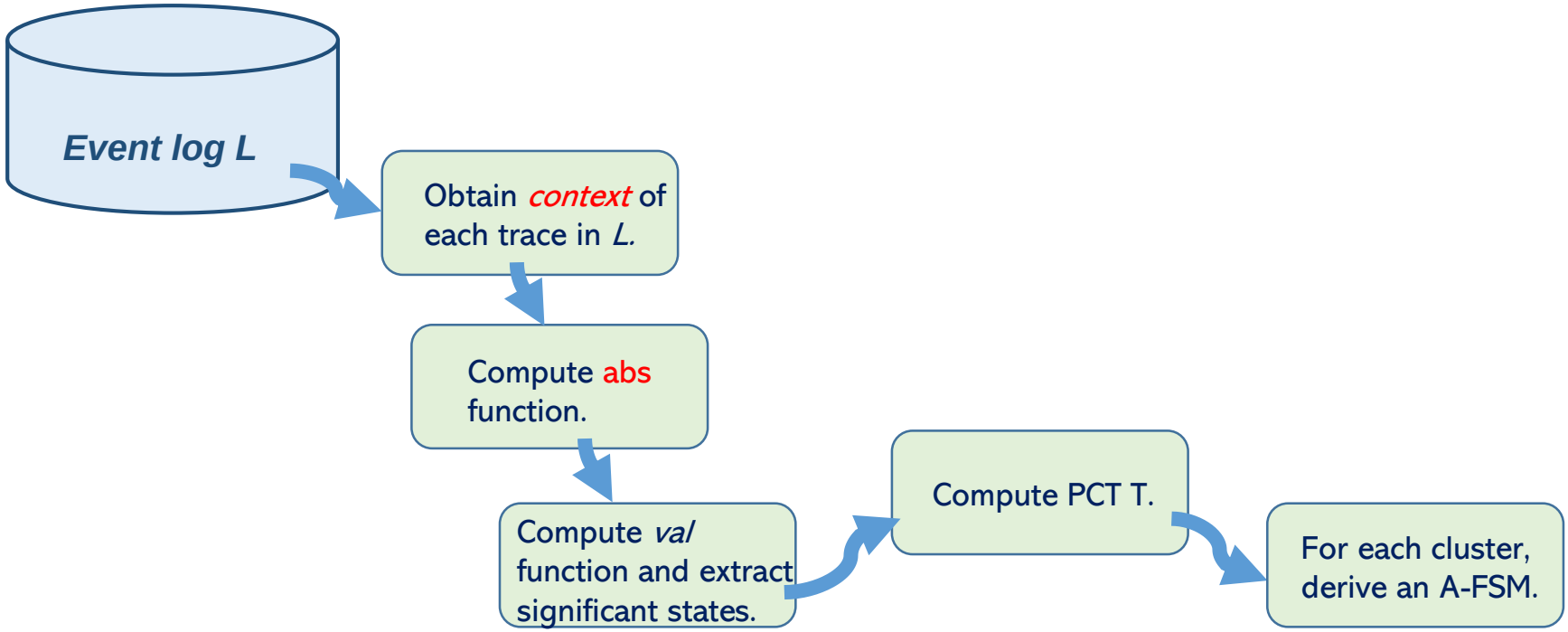
$\sigma \in L$:

(val(σ,state 1), ... ,val(σ,state k), ... ,val(σ,state n))

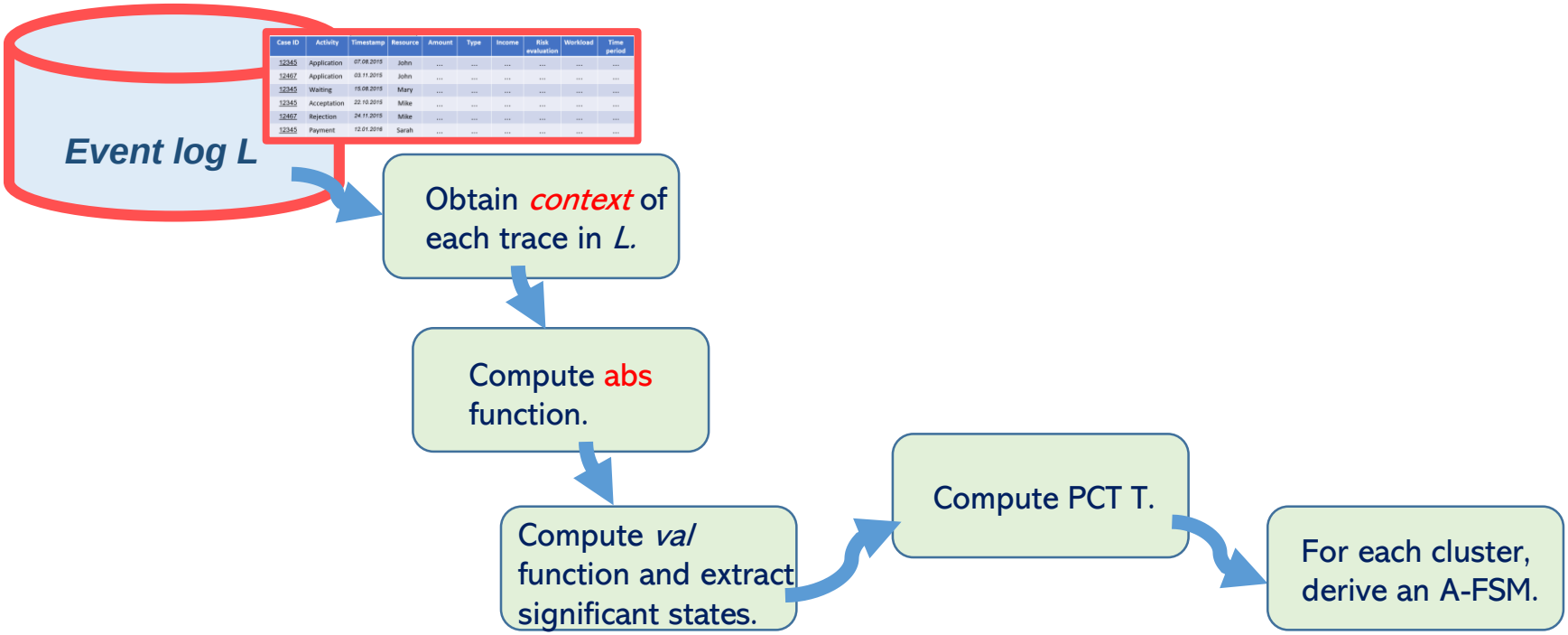
Pick the most significant states !

support variance correlation

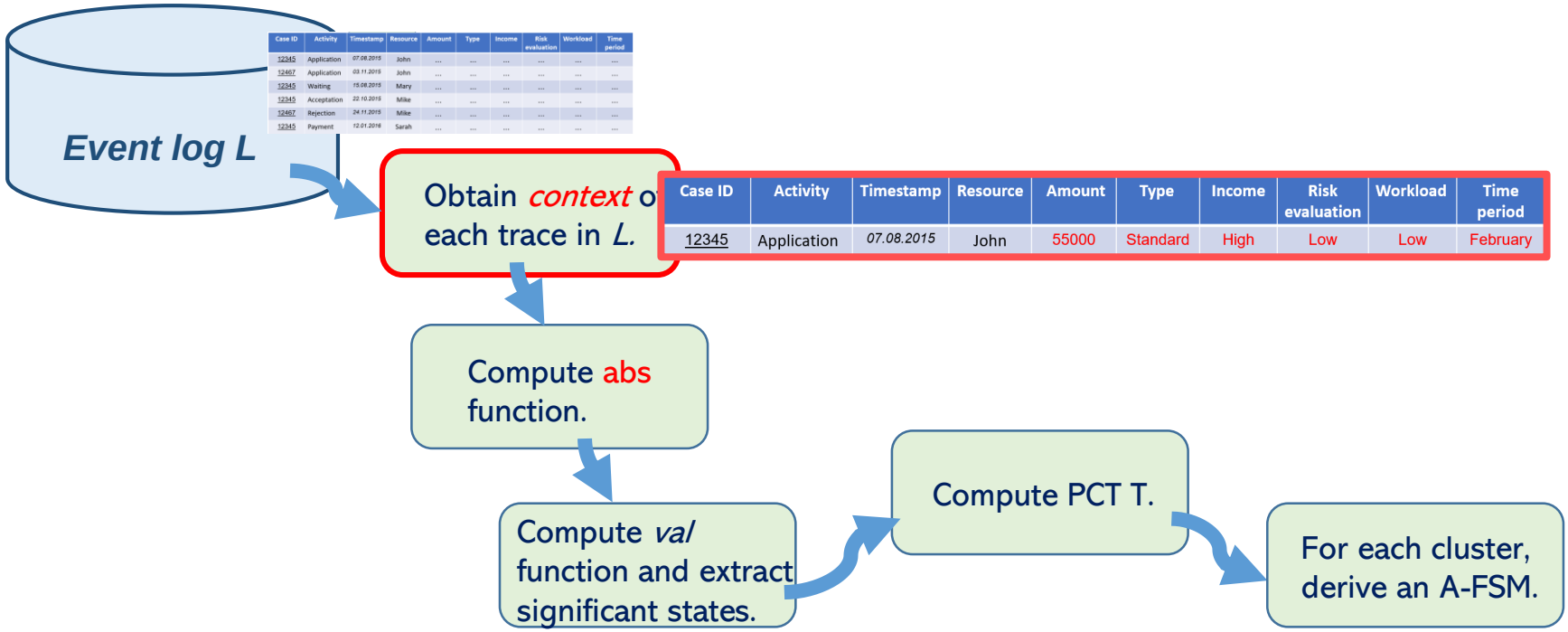
Approach - Overview



Approach - Overview

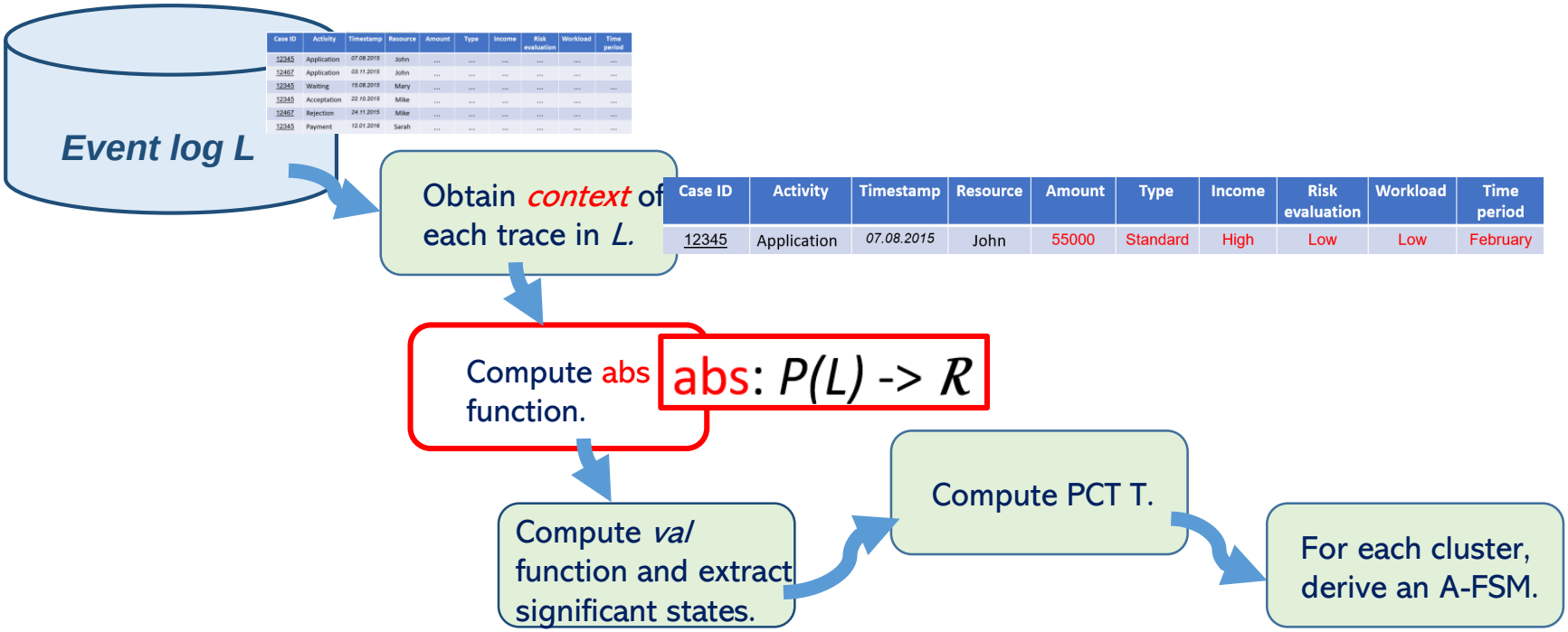


Approach - Overview



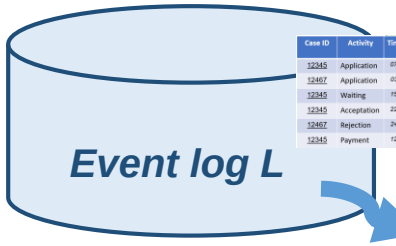
Case ID	Activity	Timestamp	Resource	Amount	Type	Income	Risk evaluation	Workload	Time period
12345	Application	07.08.2015	John	55000	Standard	High	Low	Low	February

Approach - Overview



Case ID	Activity	Timestamp	Resource	Amount	Type	Income	Risk evaluation	Workload	Time period
12345	Application	07.08.2015	John	55000	Standard	High	Low	Low	February

Approach - Overview



Case ID	Activity	Timestamp	Resource	Amount	Type	Income	Risk evaluation	Workload	Time period
12345	Application	07.08.2015	John	...	...	...	...	...	...
12467	Application	03.11.2015	John	...	...	...	...	...	...
12345	Waiting	15.08.2015	Mary	...	...	...	...	...	...
12345	Acceptation	22.10.2015	Mike	...	...	...	...	...	...
12467	Rejection	24.11.2015	Mike	...	...	...	...	...	...
12345	Payment	12.01.2016	Sarah	...	...	...	...	...	...

Obtain *context* of each trace in *L*.

Case ID	Activity	Timestamp	Resource	Amount	Type	Income	Risk evaluation	Workload	Time period
12345	Application	07.08.2015	John	55000	Standard	High	Low	Low	February

Compute abs function.

abs: *P(L)* -> $\mathcal{R}$

Compute *val* function and extract significant states.

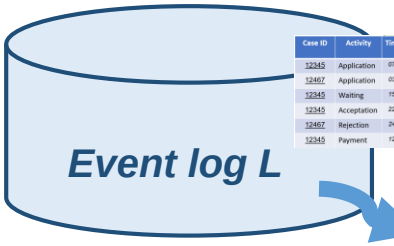
Compute PCT T.

For each cluster, derive an A-FSM.

$$val(\sigma, s) = \begin{cases} \text{NULL} & \text{if no prefix of } \sigma \text{ is mapped to } s; \\ agg(\{\hat{\mu}(\text{prefix}_1), ..., \hat{\mu}(\text{prefix}_m)\}) & \text{otherwise,} \end{cases}$$

where $\{\text{prefix}_1, ..., \text{prefix}_m\} = \{\text{prefix of } \sigma \mid abs(\text{prefix}) = s\}$

Approach - Overview



Case ID	Activity	Timestamp	Resource	Amount	Type	Income	Risk evaluation	Workload	Time period
12345	Application	07.08.2015	John	...	...	...	...	...	...
12467	Application	03.11.2015	John	...	...	...	...	...	...
12345	Waiting	15.08.2015	Mary	...	...	...	...	...	...
12345	Acceptation	22.10.2015	Mike	...	...	...	...	...	...
12467	Rejection	24.11.2015	Mike	...	...	...	...	...	...
12345	Payment	12.01.2016	Sarah	...	...	...	...	...	...

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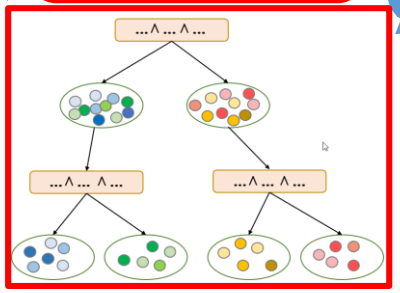
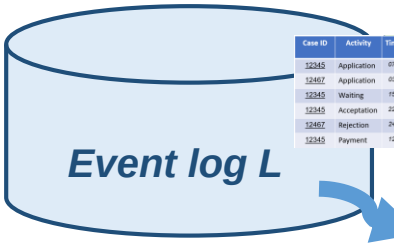


For each cluster, derive an A-FSM.

Approach - Overview



Case ID	Activity	Timestamp	Resource	Amount	Type	Income	Risk evaluation	Workload	Time period
12345	Application	07.08.2015	John	...	...	...	...	...	...
12467	Application	03.11.2015	John	...	...	...	...	...	...
12345	Waiting	15.08.2015	Mary	...	...	...	...	...	...
12345	Acceptation	22.10.2015	Mike	...	...	...	...	...	...
12467	Rejection	24.11.2015	Mike	...	...	...	...	...	...
12345	Payment	12.01.2016	Sarah	...	...	...	...	...	...

Obtain *context* of each trace in *L*.

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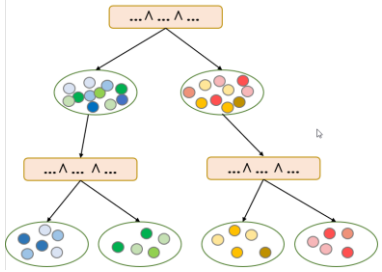
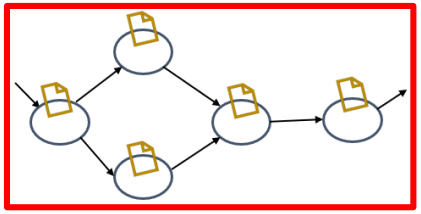
where $\{\text{prefix}_1, ..., \text{prefix}_m\} = \{\text{prefix of } \sigma \mid abs(\text{prefix}) = s\}$

Compute PCT T.

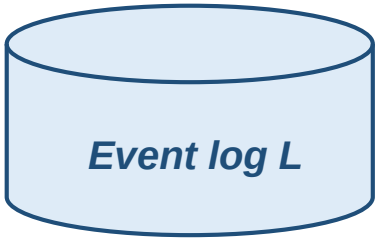


For each cluster, derive an A-FSM.



Example

the process of preparation and supervision of an academic research paper



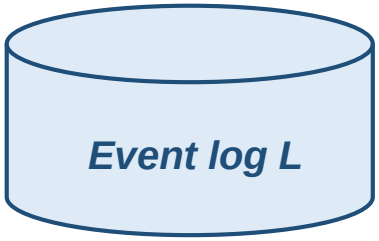
CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
1	[I, M, M, F, R, S]	high	DS	John	0.85
2	[I, M, M, F, R, S]	high	DS	John	0.95
3	[I, M, M, R, F, S]	high	DS	Brown	0.90
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
6	[I, M, M, F, M, S]	average	DS	John	0.70
7	[I, M, R, M, S]	high	SE	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60
9	[I, M, F, R, S]	high	SE	Brown	0.80

I : Introductory meeting
M: Meeting with the supervisor
F: Feedback
R: Presentation rehearsal
S: Submission

PK : Prior Knowledge

Example

the process of preparation and supervision of an academic research paper



Case dependent | External

CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
1	[I, M, M, F, R, S]	high	DS	John	0.85
2	[I, M, M, F, R, S]	high	DS	John	0.95
3	[I, M, M, R, F, S]	high	DS	Brown	0.90
4	[I, M, R, F, S]	average	SE	Brown	0.80
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6	[I, M, M, F, M, S]	average	DS	John	0.70
7	[I, M, R, M, S]	high	SE	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60
9	[I, M, F, R, S]	high	SE	Brown	0.80

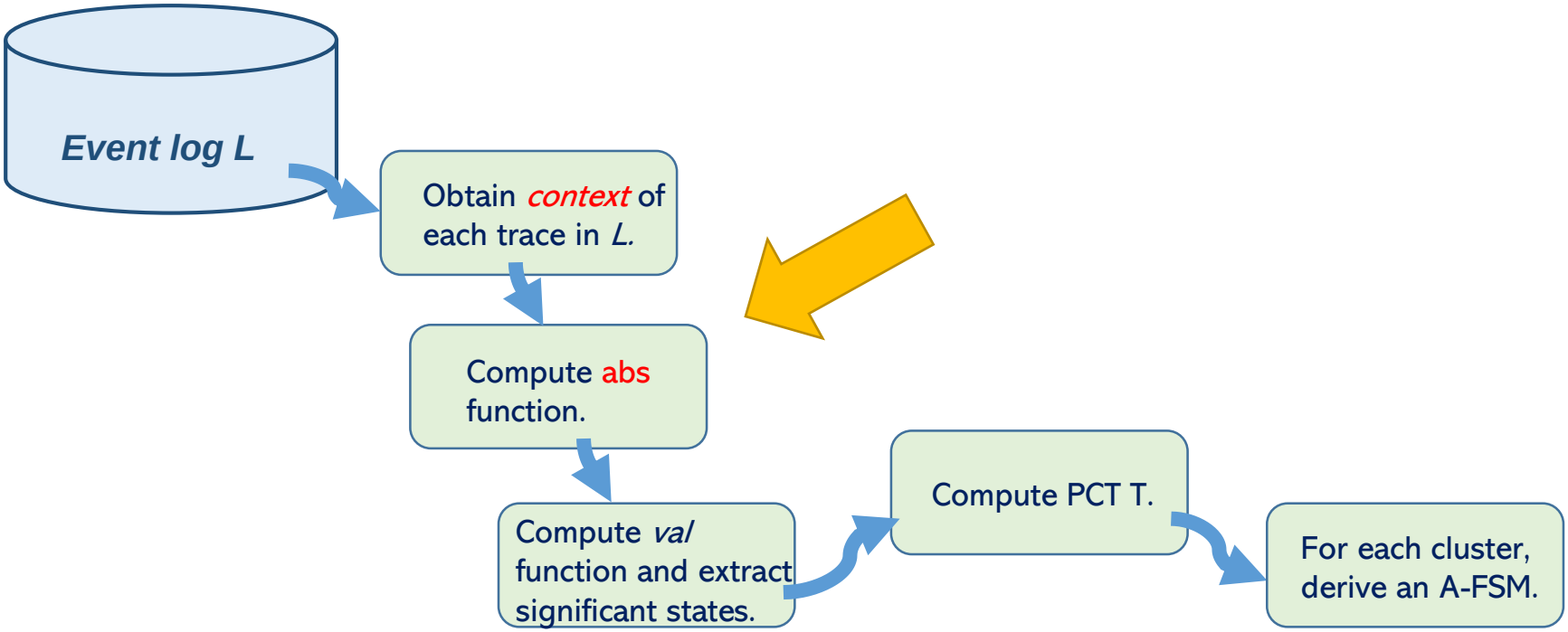
I : Introductory meeting
M: Meeting with the supervisor
F: Feedback
R: Presentation rehearsal
S: Submission

PK : Prior Knowledge

Predict final grade

abs: multiset

Approach - Overview



Example

the process of preparation and supervision of an academic research paper

P(L) $\hat{\mu}$ *range(abs)* *A*

Prefix	Prediction for prefix	CaseIDs containing prefix	Corresponding state	CaseIDs containing state	Annotation for state
[]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	0.775
[I]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{(I, 1)}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	0.775
[I, M]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{(M, 1), (I, 1)}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	0.775
[I, M, M]	0.82	[0, 1, 2, 3, 6]	{(M, 2), (I, 1)}	[0, 1, 2, 3, 6]	0.82
[I, M, M, F]	0.8	[0, 1, 2, 6]	{(M, 2), (F, 1), (I, 1)}	[0, 1, 2, 6, 8]	0.7
[I, M, M, F, M]	0.7	[0, 6]	{(F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
[I, M, M, F, M, S]	0.7	[0, 6]	{(S, 1), (F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
[I, M, M, F, R]	0.9	[1, 2]	{(R, 1), (M, 2), (F, 1), (I, 1)}	[1, 2, 3]	0.9
[I, M, M, F, R, S]	0.9	[1, 2]	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	[1, 2, 3]	0.9
[I, M, M, R]	0.9	[3]	{(R, 1), (M, 2), (I, 1)}	[3, 7]	0.8
[I, M, M, R, F]	0.9	[3]	{(R, 1), (M, 2), (F, 1), (I, 1)}	[1, 2, 3]	0.9
[I, M, M, R, F, S]	0.9	[3]	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	[1, 2, 3]	0.9
[I, M, R]	0.75	[4, 5, 7]	{(M, 1), (R, 1), (I, 1)}	[4, 5, 7]	0.75
[I, M, R, F]	0.775	[4, 5]	{(M, 1), (R, 1), (F, 1), (I, 1)}	[4, 5, 9]	0.7875
[I, M, R, F, S]	0.775	[4, 5]	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	[4, 5, 9]	0.7875
[I, M, R, M]	0.7	[7]	{(R, 1), (M, 2), (I, 1)}	[3, 7]	0.8
[I, M, R, M, S]	0.7	[7]	{(R, 1), (M, 2), (I, 1), (S, 1)}	[7]	0.7
[I, M, F]	0.7	[8, 9]	{(M, 1), (F, 1), (I, 1)}	[8, 9]	0.7
[I, M, F, M]	0.6	[8]	{(M, 2), (F, 1), (I, 1)}	[0, 1, 2, 6, 8]	0.7
[I, M, F, M, M]	0.6	[8]	{(F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
[I, M, F, M, M, S]	0.6	[8]	{(S, 1), (F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
[I, M, F, R]	0.8	[9]	{(M, 1), (R, 1), (F, 1), (I, 1)}	[4, 5, 9]	0.7875
[I, M, F, R, S]	0.8	[9]	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	[4, 5, 9]	0.7875

Example

the process of preparation and supervision of an academic research paper

P(L) *μ̂* *range(abs)* *A*

Prefix	Prediction for prefix	CaseIDs containing prefix	Corresponding state	CaseIDs containing state	Annotation for state
[]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	0.775
[I]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{(I, 1)}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	0.775
[I, M]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{(M, 1), (I, 1)}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	0.775
[I, M, M]	0.82	[0, 1, 2, 3, 6]	{(M, 2), (I, 1)}	[0, 1, 2, 3, 6]	0.82
[I, M, M, F]	0.8	[0, 1, 2, 6]	{(M, 2), (F, 1), (I, 1)}	[0, 1, 2, 6, 8]	0.7
[I, M, M, F, M]	0.7	[0, 6]	{(F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
[I, M, M, F, M, S]	0.7	[0, 6]	{(S, 1), (F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
[I, M, M, F, R]	0.9	[1, 2]	{(R, 1), (M, 2), (F, 1), (I, 1)}	[1, 2, 3]	0.9
[I, M, M, F, R, S]	0.9	[1, 2]	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	[1, 2, 3]	0.9
[I, M, M, R]	0.9	[3]	{(R, 1), (M, 2), (I, 1)}	[3, 7]	0.8
[I, M, M, R, F]	0.9	[3]	{(R, 1), (M, 2), (F, 1), (I, 1)}	[1, 2, 3]	0.9
[I, M, M, R, F, S]	0.9	[3]	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	[1, 2, 3]	0.9
[I, M, R]	0.75	[4, 5, 7]	{(M, 1), (R, 1), (I, 1)}	[4, 5, 7]	0.75
[I, M, R, F]	0.775	[4, 5]	{(M, 1), (R, 1), (F, 1), (I, 1)}	[4, 5, 9]	0.7875
[I, M, R, F, S]	0.775	[4, 5]	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	[4, 5, 9]	0.7875
[I, M, R, M]	0.7	[7]	{(R, 1), (M, 2), (I, 1)}	[3, 7]	0.8
[I, M, R, M, S]	0.7	[7]	{(R, 1), (M, 2), (I, 1), (S, 1)}	[7]	0.7
[I, M, F]	0.7	[8, 9]	{(M, 1), (F, 1), (I, 1)}	[8, 9]	0.7
[I, M, F, M]	0.6	[8]	{(M, 2), (F, 1), (I, 1)}	[0, 1, 2, 6, 8]	0.7
[I, M, F, M, M]	0.6	[8]	{(F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
[I, M, F, M, M, S]	0.6	[8]	{(S, 1), (F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
[I, M, F, R]	0.8	[9]	{(M, 1), (R, 1), (F, 1), (I, 1)}	[4, 5, 9]	0.7875
[I, M, F, R, S]	0.8	[9]	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	[4, 5, 9]	0.7875

Example

the process of preparation and supervision of an academic research paper

	P(L)	*μ̂*		*range(abs)*		*A*
	Prefix	Prediction for prefix	CaseIDs containing prefix	Corresponding state	CaseIDs containing state	Annotation for state
	[]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	0.775
	[I]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{(I, 1)}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	0.775
	[I, M]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{(M, 1), (I, 1)}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	0.775
	[I, M, M]	0.82	[0, 1, 2, 3, 6]	{(M, 2), (I, 1)}	[0, 1, 2, 3, 6]	0.82
	[I, M, M, F]	0.8	[0, 1, 2, 6]	{(M, 2), (F, 1), (I, 1)}	[0, 1, 2, 6, 8]	0.7
	[I, M, M, F, M]	0.7	[0, 6]	{(F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
	[I, M, M, F, M, S]	0.7	[0, 6]	{(S, 1), (F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
	[I, M, M, F, R]	0.9	[1, 2]	{(R, 1), (M, 2), (F, 1), (I, 1)}	[1, 2, 3]	0.9
	[I, M, M, F, R, S]	0.9	[1, 2]	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	[1, 2, 3]	0.9
	[I, M, M, R]	0.9	[3]	{(R, 1), (M, 2), (I, 1)}	[3, 7]	0.8
	[I, M, M, R, F]	0.9	[3]	{(R, 1), (M, 2), (F, 1), (I, 1)}	[1, 2, 3]	0.9
	[I, M, M, R, F, S]	0.9	[3]	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	[1, 2, 3]	0.9
	[I, M, R]	0.75	[4, 5, 7]	{(M, 1), (R, 1), (I, 1)}	[4, 5, 7]	0.75
	[I, M, R, F]	0.775	[4, 5]	{(M, 1), (R, 1), (F, 1), (I, 1)}	[4, 5, 9]	0.7875
	[I, M, R, F, S]	0.775	[4, 5]	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	[4, 5, 9]	0.7875
	[I, M, R, M]	0.7	[7]	{(R, 1), (M, 2), (I, 1)}	[3, 7]	0.8
	[I, M, R, M, S]	0.7	[7]	{(R, 1), (M, 2), (I, 1), (S, 1)}	[7]	0.7
	[I, M, F]	0.7	[8, 9]	{(M, 1), (F, 1), (I, 1)}	[8, 9]	0.7
	[I, M, F, M]	0.6	[8]	{(M, 2), (F, 1), (I, 1)}	[0, 1, 2, 6, 8]	0.7
	[I, M, F, M, M]	0.6	[8]	{(F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
	[I, M, F, M, M, S]	0.6	[8]	{(S, 1), (F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
	[I, M, F, R]	0.8	[9]	{(M, 1), (R, 1), (F, 1), (I, 1)}	[4, 5, 9]	0.7875
	[I, M, F, R, S]	0.8	[9]	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	[4, 5, 9]	0.7875

Example

the process of preparation and supervision of an academic research paper

P(L)	$\hat{\mu}$		*range*(abs)		*A*
Prefix	Prediction for prefix	CaseIDs containing prefix	Corresponding state	CaseIDs containing state	Annotation for state
[]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	0.775
[I]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{(I, 1)}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	0.775
[I, M]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{(M, 1), (I, 1)}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	0.775
[I, M, M]	0.82	[0, 1, 2, 3, 6]	{(M, 2), (I, 1)}	[0, 1, 2, 3, 6]	0.82
[I, M, M, F]	0.8	[0, 1, 2, 6]	{(M, 2), (F, 1), (I, 1)}	[0, 1, 2, 6, 8]	0.7
[I, M, M, F, M]	0.7	[0, 6]	{(F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
[I, M, M, F, M, S]	0.7	[0, 6]	{(S, 1), (F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
[I, M, M, F, R]	0.9	[1, 2]	{(R, 1), (M, 2), (F, 1), (I, 1)}	[1, 2, 3]	0.9
[I, M, M, F, R, S]	0.9	[1, 2]	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	[1, 2, 3]	0.9
[I, M, M, R]	0.9	[3]	{(R, 1), (M, 2), (I, 1)}	[3, 7]	0.8
[I, M, M, R, F]	0.9	[3]	{(R, 1), (M, 2), (F, 1), (I, 1)}	[1, 2, 3]	0.9
[I, M, M, R, F, S]	0.9	[3]	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	[1, 2, 3]	0.9
[I, M, R]	0.75	[4, 5, 7]	{(M, 1), (R, 1), (I, 1)}	[4, 5, 7]	0.75
[I, M, R, F]	0.775	[4, 5]	{(M, 1), (R, 1), (F, 1), (I, 1)}	[4, 5, 9]	0.7875
[I, M, R, F, S]	0.775	[4, 5]	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	[4, 5, 9]	0.7875
[I, M, R, M]	0.7	[7]	{(R, 1), (M, 2), (I, 1)}	[3, 7]	0.8
[I, M, R, M, S]	0.7	[7]	{(R, 1), (M, 2), (I, 1), (S, 1)}	[7]	0.7
[I, M, F]	0.7	[8, 9]	{(M, 1), (F, 1), (I, 1)}	[8, 9]	0.7
[I, M, F, M]	0.6	[8]	{(M, 2), (F, 1), (I, 1)}	[0, 1, 2, 6, 8]	0.7
[I, M, F, M, M]	0.6	[8]	{(F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
[I, M, F, M, M, S]	0.6	[8]	{(S, 1), (F, 1), (I, 1), (M, 3)}	[0, 6, 8]	0.65
[I, M, F, R]	0.8	[9]	{(M, 1), (R, 1), (F, 1), (I, 1)}	[4, 5, 9]	0.7875
[I, M, F, R, S]	0.8	[9]	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	[4, 5, 9]	0.7875

Example

the process of preparation and supervision of an academic research paper

P(L) $\hat{\mu}$ *range(abs)* *A*

Prefix	Prediction for prefix	CaseIDs containing prefix	Corresponding state	CaseIDs containing state	Annotation for state
[]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9	0.775
[I]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{(I, 1)}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9	0.775
[I, M]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{(M, 1), (I, 1)}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9	0.775
[I, M, M]	0.82	[0, 1, 2, 3, 6]	{(M, 2), (I, 1)}	[0, 1, 2, 3, 6	0.82
[I, M, M, F]	0.8	[0, 1, 2, 6]	{(M, 2), (F, 1), (I, 1)}	[0, 1, 2, 6, 8	0.7
[I, M, M, F, M]	0.7	[0, 6]	{(F, 1), (I, 1), (M, 3)}	[0, 6, 8	0.65
[I, M, M, F, M, S]	0.7	[0, 6]	{(S, 1), (F, 1), (I, 1), (M, 3)}	[0, 6, 8	0.65
[I, M, M, F, R]	0.9	[1, 2]	{(R, 1), (M, 2), (F, 1), (I, 1)}	[1, 2, 3	0.9
[I, M, M, F, R, S]	0.9	[1, 2]	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	[1, 2, 3	0.9
[I, M, M, R]	0.9	[3]	{(R, 1), (M, 2), (I, 1)}	[3, 7	0.8
[I, M, M, R, F]	0.9	[3]	{(R, 1), (M, 2), (F, 1), (I, 1)}	[1, 2, 3	0.9
[I, M, M, R, F, S]	0.9	[3]	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	[1, 2, 3	0.9
[I, M, R]	0.75	[4, 5, 7]	{(M, 1), (R, 1), (I, 1)}	[4, 5, 7	0.75
[I, M, R, F]	0.775	[4, 5]	{(M, 1), (R, 1), (F, 1), (I, 1)}	[4, 5, 9	0.7875
[I, M, R, F, S]	0.775	[4, 5]	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	[4, 5, 9	0.7875
[I, M, R, M]	0.7	[7]	{(R, 1), (M, 2), (I, 1)}	[3, 7	0.8
[I, M, R, M, S]	0.7	[7]	{(R, 1), (M, 2), (I, 1), (S, 1)}	[7	0.7
[I, M, F]	0.7	[8, 9]	{(M, 1), (F, 1), (I, 1)}	[8, 9	0.7
[I, M, F, M]	0.6	[8]	{(M, 2), (F, 1), (I, 1)}	[0, 1, 2, 6, 8	0.7
[I, M, F, M, M]	0.6	[8]	{(F, 1), (I, 1), (M, 3)}	[0, 6, 8	0.65
[I, M, F, M, M, S]	0.6	[8]	{(S, 1), (F, 1), (I, 1), (M, 3)}	[0, 6, 8	0.65
[I, M, F, R]	0.8	[9]	{(M, 1), (R, 1), (F, 1), (I, 1)}	[4, 5, 9	0.7875
[I, M, F, R, S]	0.8	[9]	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	[4, 5, 9	0.7875

Example

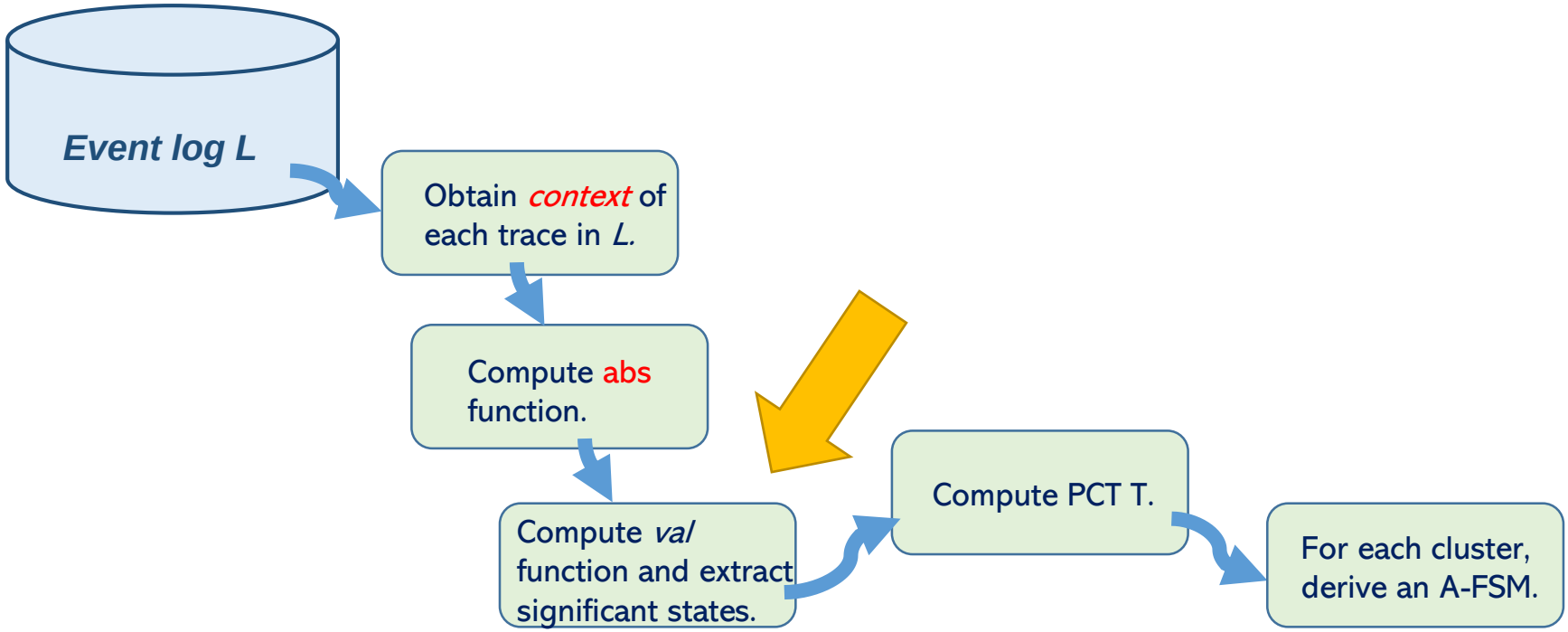
the process of preparation and supervision of an academic research paper

P(L) $\hat{\mu}$ *range(abs)* *A*

Prefix	Prediction for prefix	CaseIDs containing prefix	Corresponding state	CaseIDs containing state	Annotation for state
[]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9	0.775
[I]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{(I, 1)}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9	0.775
[I, M]	0.775	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9]	{(M, 1), (I, 1)}	[0, 1, 2, 3, 4, 5, 6, 7, 8, 9	0.775
[I, M, M]	0.82	[0, 1, 2, 3, 6]	{(M, 2), (I, 1)}	[0, 1, 2, 3, 6	0.82
[I, M, M, F]	0.8	[0, 1, 2, 6]	{(M, 2), (F, 1), (I, 1)}	[0, 1, 2, 6, 8	0.7
[I, M, M, F, M]	0.7	[0, 6]	{(F, 1), (I, 1), (M, 3)}	[0, 6, 8	0.65
[I, M, M, F, M, S]	0.7	[0, 6]	{(S, 1), (F, 1), (I, 1), (M, 3)}	[0, 6, 8	0.65
[I, M, M, F, R]	0.9	[1, 2]	{(R, 1), (M, 2), (F, 1), (I, 1)}	[1, 2, 3	0.9
[I, M, M, F, R, S]	0.9	[1, 2]	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	[1, 2, 3	0.9
[I, M, M, R]	0.9	[3]	{(R, 1), (M, 2), (I, 1)}	[3, 7	0.8
[I, M, M, R, F]	0.9	[3]	{(R, 1), (M, 2), (F, 1), (I, 1)}	[1, 2, 3	0.9
[I, M, M, R, F, S]	0.9	[3]	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	[1, 2, 3	0.9
[I, M, R]	0.75	[4, 5, 7]	{(M, 1), (R, 1), (I, 1)}	[4, 5, 7	0.75
[I, M, R, F]	0.775	[4, 5]	{(M, 1), (R, 1), (F, 1), (I, 1)}	[4, 5, 9	0.775
[I, M, R, F, S]	0.775	[4, 5]	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	[4, 5, 9	0.775
[I, M, R, M]	0.7	[7]	{(R, 1), (M, 2), (I, 1)}	[3, 7	0.8
[I, M, R, M, S]	0.7	[7]	{(R, 1), (M, 2), (I, 1), (S, 1)}	[7	0.7
[I, M, F]	0.7	[8, 9]	{(M, 1), (F, 1), (I, 1)}	[8, 9	0.7
[I, M, F, M]	0.6	[8]	{(M, 2), (F, 1), (I, 1)}	[0, 1, 2, 6, 8	0.7
[I, M, F, M, M]	0.6	[8]	{(F, 1), (I, 1), (M, 3)}	[0, 6, 8	0.65
[I, M, F, M, M, S]	0.6	[8]	{(S, 1), (F, 1), (I, 1), (M, 3)}	[0, 6, 8	0.65
[I, M, F, R]	0.8	[9]	{(M, 1), (R, 1), (F, 1), (I, 1)}	[4, 5, 9	0.7875
[I, M, F, R, S]	0.8	[9]	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	[4, 5, 9	0.7875

Not only one A-FSM !

Approach - Overview



Example

the process of preparation and supervision of an academic research paper

Computing the *val* function for each trace and each state:

States	Case0	Case1	Case2	Case3	Case4	Case5	Case6	Case7	Case8	Case9
{}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 1), (I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 2), (I, 1)}	0.82	0.82	0.82	0.82	None	None	0.82	None	None	None
{(M, 2), (F, 1), (I, 1)}	0.8	0.8	0.8	None	None	None	0.8	None	0.6	None
{(F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
{(S, 1), (F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
{(R, 1), (M, 2), (F, 1), (I, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
{(R, 1), (M, 2), (I, 1)}	None	None	None	0.9	None	None	None	0.7	None	None
{(M, 1), (R, 1), (I, 1)}	None	None	None	None	0.75	0.75	None	0.75	None	None
{(M, 1), (R, 1), (F, 1), (I, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(R, 1), (M, 2), (I, 1), (S, 1)}	None	None	None	None	None	None	None	0.7	None	None
{(M, 1), (F, 1), (I, 1)}	None	None	None	None	None	None	None	None	0.7	0.7

Example

the process of preparation and supervision of an academic research paper

Computing the *val* function for each trace and each state:

States	Case0	Case1	Case2	Case3	Case4	Case5	Case6	Case7	Case8	Case9
{}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 1), (I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775

$$val(\sigma, s) = \begin{cases} \text{NULL} & \text{if no prefix of } \sigma \text{ is mapped to } s; \\ agg(\{\hat{\mu}(\text{prefix}_1), ..., \hat{\mu}(\text{prefix}_m)\}) & \text{otherwise,} \end{cases}$$

$$\text{where } \{\text{prefix}_1, ..., \text{prefix}_m\} = \{\text{prefix of } \sigma \mid abs(\text{prefix}) = s\}$$

{(M, 1), (R, 1), (I, 1)}	None	None	None	None	0.75	0.75	None	0.75	None	None
{(M, 1), (R, 1), (F, 1), (I, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(R, 1), (M, 2), (I, 1), (S, 1)}	None	None	None	None	None	None	None	0.7	None	None
{(M, 1), (F, 1), (I, 1)}	None	None	None	None	None	None	None	None	0.7	0.7

Example

the process of preparation and supervision of an academic research paper

Computing the *val* function for each trace and each state:

(val(σ1,s1),val(σ1,s2), ... ,val(σ1,s15))

	States	Case0	Case1	Case2	Case3	Case4	Case5	Case6	Case7	Case8	Case9
s1 →	{}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
s2 →	{(I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
	{(M, 1), (I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
	{(M, 2), (I, 1)}	0.82	0.82	0.82	0.82	None	None	0.82	None	None	None
	{(M, 2), (F, 1), (I, 1)}	0.8	0.8	0.8	None	None	None	0.8	None	0.6	None
	{(F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
	{(S, 1), (F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
	{(R, 1), (M, 2), (F, 1), (I, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
	{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
	{(R, 1), (M, 2), (I, 1)}	None	None	None	0.9	None	None	None	0.7	None	None
	{(M, 1), (R, 1), (I, 1)}	None	None	None	None	0.75	0.75	None	0.75	None	None
	{(M, 1), (R, 1), (F, 1), (I, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
	{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
	{(R, 1), (M, 2), (I, 1), (S, 1)}	None	None	None	None	None	None	None	0.7	None	None
s15 →	{(M, 1), (F, 1), (I, 1)}	None	None	None	None	None	None	None	None	0.7	0.7

Example

the process of preparation and supervision of an academic research paper

Descriptive features

context

CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
1	[I, M, M, F, R, S]	high	DS	John	0.85
2	[I, M, M, F, R, S]	high	DS	John	0.95
3	[I, M, M, R, F, S]	high	DS	Brown	0.90
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
6	[I, M, M, F, M, S]	average	DS	John	0.70
7	[I, M, R, M, S]	high	SE	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60
9	[I, M, F, R, S]	high	SE	Brown	0.80

Target features

vectors

States	Case0	Case1	Case2	Case3	Case4	Case5	Case6	Case7	Case8	Case9
{}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 1), (I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 2), (I, 1)}	0.82	0.82	0.82	0.82	None	None	0.82	None	None	None
{(M, 2), (F, 1), (I, 1)}	0.8	0.8	0.8	None	None	None	0.8	None	0.6	None
{(F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
{(S, 1), (F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
{(R, 1), (M, 2), (F, 1), (I, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
{(R, 1), (M, 2), (I, 1)}	None	None	None	0.9	None	None	None	0.7	None	None
{(M, 1), (R, 1), (I, 1)}	None	None	None	None	0.75	0.75	None	0.75	None	None
{(M, 1), (R, 1), (F, 1), (I, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(R, 1), (M, 2), (I, 1), (S, 1)}	None	None	None	None	None	None	None	0.7	None	None
{(M, 1), (F, 1), (I, 1)}	None	None	None	None	None	None	None	None	0.7	0.7

Example

the process of preparation and supervision of an academic research paper

Descriptive features

context

CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
1	[I, M, M, F, R, S]	high	DS	John	0.85
2	[I, M, M, F, R, S]	high	DS	John	0.95
3	[I, M, M, R, F, S]	high	DS	Brown	0.90
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
6	[I, M, M, F, M, S]	average	DS	John	0.70
7	[I, M, R, M, S]	high	SE	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60
9	[I, M, F, R, S]	high	SE	Brown	0.80

Target features

vectors

States	Case0	Case1	Case2	Case3	Case4	Case5	Case6	Case7	Case8	Case9
{}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 1), (I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 2), (I, 1)}	0.82	0.82	0.82	0.82	None	None	0.82	None	None	None
{(M, 2), (F, 1), (I, 1)}	0.8	0.8	0.8	None	None	None	0.8	None	0.6	None
{(F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
{(S, 1), (F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
{(R, 1), (M, 2), (F, 1), (I, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
{(R, 1), (M, 2), (I, 1)}	None	None	None	0.9	None	None	None	0.7	None	None
{(M, 1), (R, 1), (I, 1)}	None	None	None	None	0.75	0.75	None	0.75	None	None
{(M, 1), (R, 1), (F, 1), (I, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(R, 1), (M, 2), (I, 1), (S, 1)}	None	None	None	None	None	None	None	0.7	None	None
{(M, 1), (F, 1), (I, 1)}	None	None	None	None	None	None	None	None	0.7	0.7

Example

the process of preparation and supervision of an academic research paper

Descriptive features

context

CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
1	[I, M, M, F, R, S]	high	DS	John	0.85
2	[I, M, M, F, R, S]	high	DS	John	0.95
3	[I, M, M, R, F, S]	high	DS	Brown	0.90
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
6	[I, M, M, F, M, S]	average	DS	John	0.70
7	[I, M, R, M, S]	high	SE	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60
9	[I, M, F, R, S]	high	SE	Brown	0.80

Target features

vectors

States	Case0	Case1	Case2	Case3	Case4	Case5	Case6	Case7	Case8	Case9
{}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 1), (I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 2), (I, 1)}	0.82	0.82	0.82	0.82	None	None	0.82	None	None	None
{(M, 2), (F, 1), (I, 1)}	0.8	0.8	0.8	None	None	None	0.8	None	0.6	None
{(F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
{(S, 1), (F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
{(R, 1), (M, 2), (F, 1), (I, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
{(R, 1), (M, 2), (I, 1)}	None	None	None	0.9	None	None	None	0.7	None	None
{(M, 1), (R, 1), (I, 1)}	None	None	None	None	0.75	0.75	None	0.75	None	None
{(M, 1), (R, 1), (F, 1), (I, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(R, 1), (M, 2), (I, 1), (S, 1)}	None	None	None	None	None	None	None	0.7	None	None
{(M, 1), (F, 1), (I, 1)}	None	None	None	None	None	None	None	None	0.7	0.7

Example

the process of preparation and supervision of an academic research paper

Descriptive features

context

CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
1	[I, M, M, F, R, S]	high	DS	John	0.85
2	[I, M, M, F, R, S]	high	DS	John	0.95
3	[I, M, M, R, F, S]	high	DS	Brown	0.90
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
6	[I, M, M, F, M, S]	average	DS	John	0.70
7	[I, M, R, M, S]	high	SE	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60
9	[I, M, F, R, S]	high	SE	Brown	0.80

Target features

vectors

States	Case0	Case1	Case2	Case3	Case4	Case5	Case6	Case7	Case8	Case9
{}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 1), (I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 2), (I, 1)}	0.82	0.82	0.82	0.82	None	None	0.82	None	None	None
{(M, 2), (F, 1), (I, 1)}	0.8	0.8	0.8	None	None	None	0.8	None	0.6	None
{(F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
{(S, 1), (F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
{(R, 1), (M, 2), (F, 1), (I, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
{(R, 1), (M, 2), (I, 1)}	None	None	None	0.9	None	None	None	0.7	None	None
{(M, 1), (R, 1), (I, 1)}	None	None	None	None	0.75	0.75	None	0.75	None	None
{(M, 1), (R, 1), (F, 1), (I, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(R, 1), (M, 2), (I, 1), (S, 1)}	None	None	None	None	None	None	None	0.7	None	None
{(M, 1), (F, 1), (I, 1)}	None	None	None	None	None	None	None	None	0.7	0.7

Example

the process of preparation and supervision of an academic research paper

Descriptive features

context

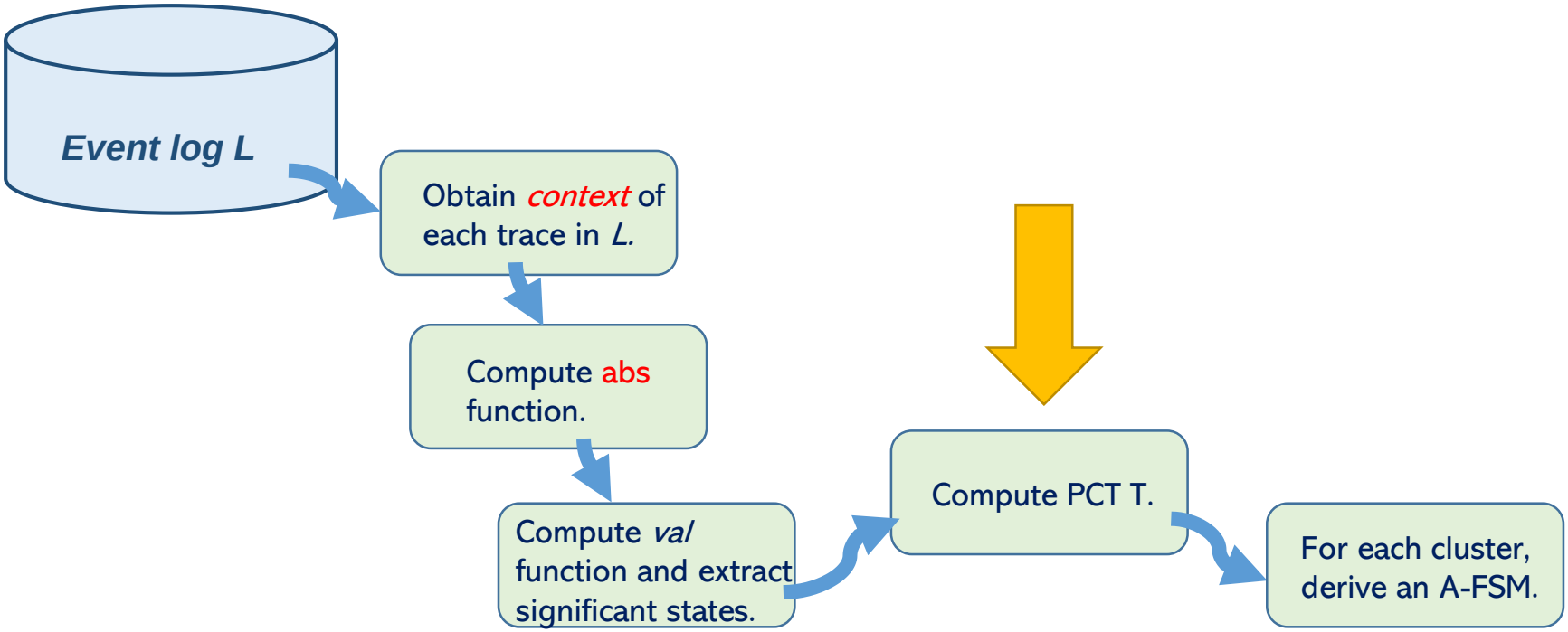
CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
1	[I, M, M, F, R, S]	high	DS	John	0.85
2	[I, M, M, F, R, S]	high	DS	John	0.95
3	[I, M, M, R, F, S]	high	DS	Brown	0.90
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
6	[I, M, M, F, M, S]	average	DS	John	0.70
7	[I, M, R, M, S]	high	SE	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60
9	[I, M, F, R, S]	high	SE	Brown	0.80

Target features

vectors

States	Case0	Case1	Case2	Case3	Case4	Case5	Case6	Case7	Case8	Case9
{}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 1), (I, 1)}	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775	0.775
{(M, 2), (I, 1)}	0.82	0.82	0.82	0.82	None	None	0.82	None	None	None
{(M, 2), (F, 1), (I, 1)}	0.8	0.8	0.8	None	None	None	0.8	None	0.6	None
{(F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
{(S, 1), (F, 1), (I, 1), (M, 3)}	0.7	None	None	None	None	None	0.7	None	0.6	None
{(R, 1), (M, 2), (F, 1), (I, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
{(I, 1), (R, 1), (F, 1), (M, 2), (S, 1)}	None	0.9	0.9	0.9	None	None	None	None	None	None
{(R, 1), (M, 2), (I, 1)}	None	None	None	0.9	None	None	None	0.7	None	None
{(M, 1), (R, 1), (I, 1)}	None	None	None	None	0.75	0.75	None	0.75	None	None
{(M, 1), (R, 1), (F, 1), (I, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(I, 1), (R, 1), (F, 1), (M, 1), (S, 1)}	None	None	None	None	0.775	0.775	None	None	None	0.8
{(R, 1), (M, 2), (I, 1), (S, 1)}	None	None	None	None	None	None	None	0.7	None	None
{(M, 1), (F, 1), (I, 1)}	None	None	None	None	None	None	None	None	0.7	0.7

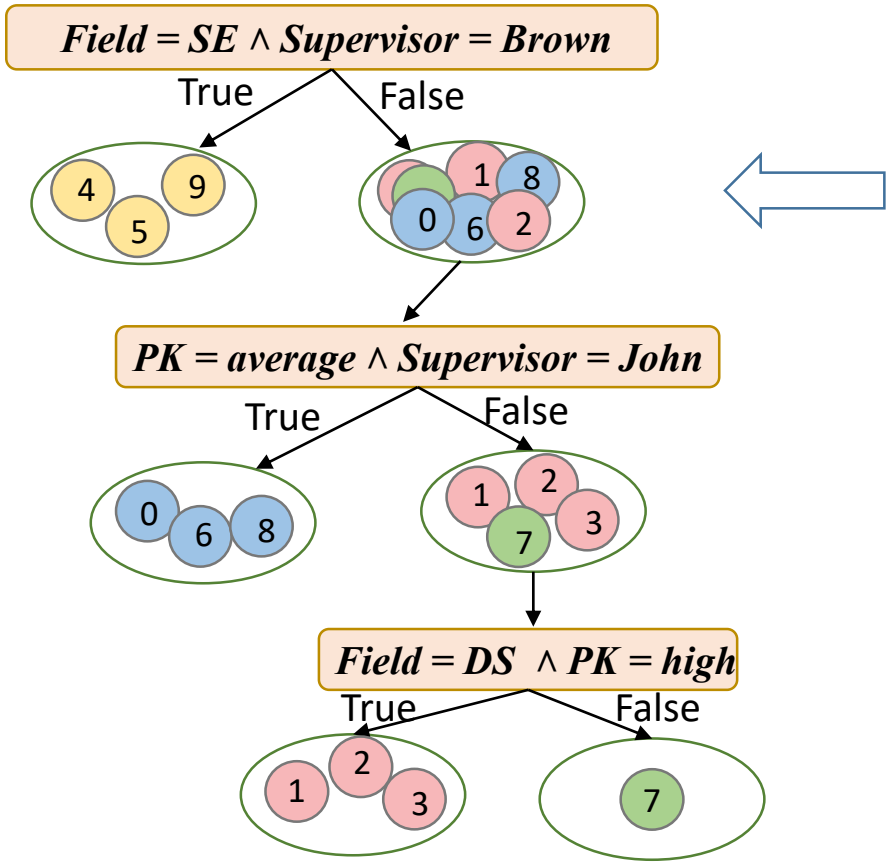
Approach - Overview



Example

the process of preparation and supervision of an academic research paper

Clustering function given by the PCT:

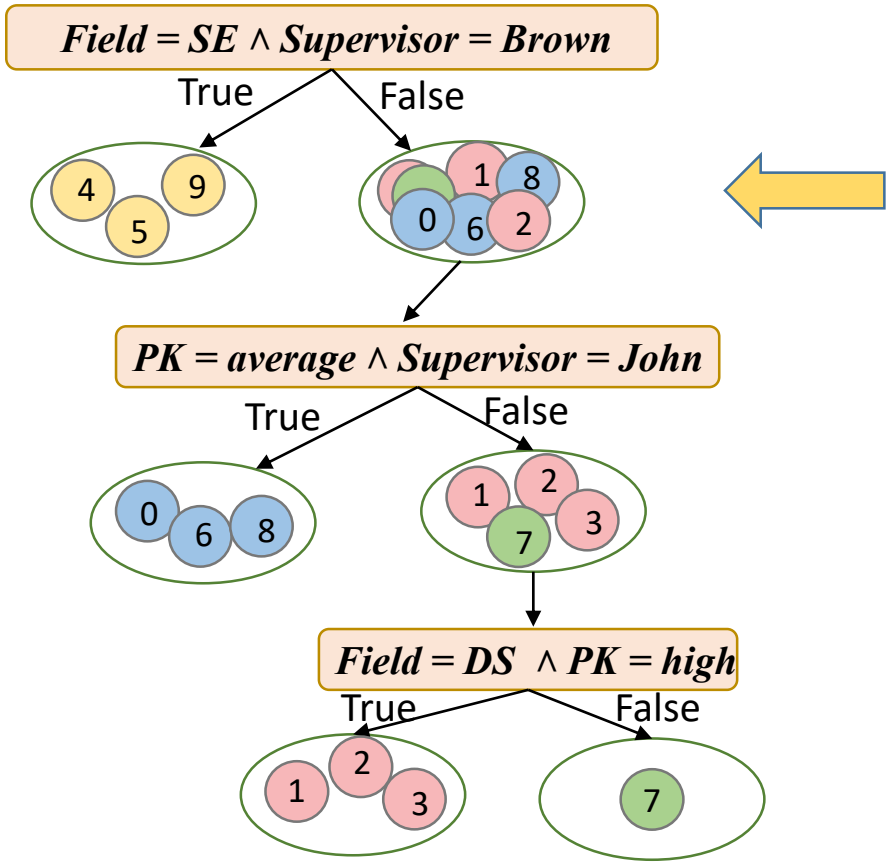


CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
1	[I, M, M, F, R, S]	high	DS	John	0.85
2	[I, M, M, F, R, S]	high	DS	John	0.95
3	[I, M, M, R, F, S]	high	DS	Brown	0.90
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
6	[I, M, M, F, M, S]	average	DS	John	0.70
7	[I, M, R, M, S]	high	SE	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60
9	[I, M, F, R, S]	high	SE	Brown	0.80

Example

the process of preparation and supervision of an academic research paper

Clustering function given by the PCT:

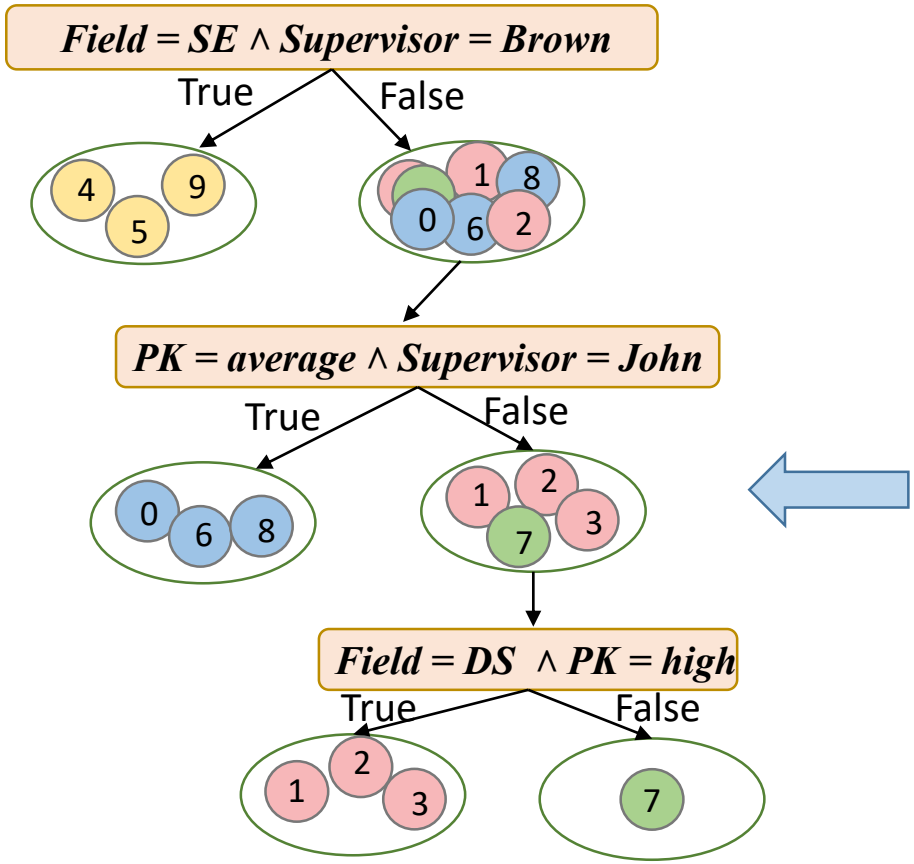


CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
1	[I, M, M, F, R, S]	high	DS	John	0.85
2	[I, M, M, F, R, S]	high	DS	John	0.95
3	[I, M, M, R, F, S]	high	DS	Brown	0.90
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
6	[I, M, M, F, M, S]	average	DS	John	0.70
7	[I, M, R, M, S]	high	SE	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60
9	[I, M, F, R, S]	high	SE	Brown	0.80

Example

the process of preparation and supervision of an academic research paper

Clustering function given by the PCT:

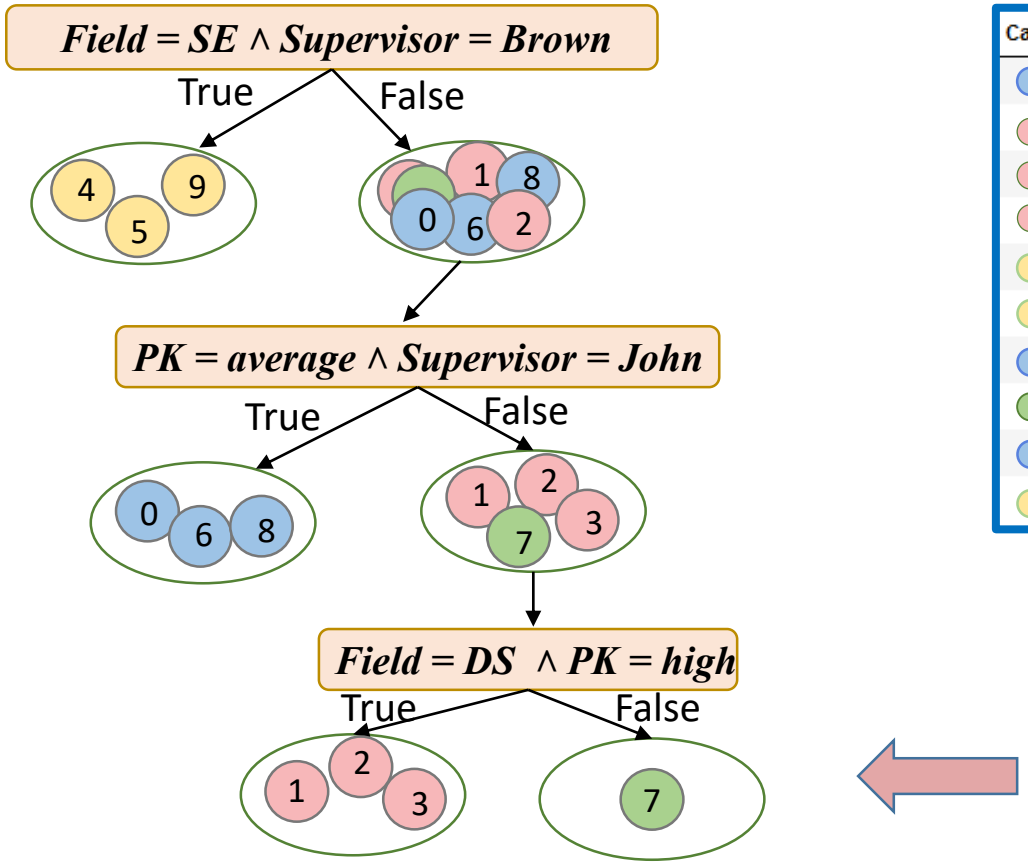


CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
1	[I, M, M, F, R, S]	high	DS	John	0.85
2	[I, M, M, F, R, S]	high	DS	John	0.95
3	[I, M, M, R, F, S]	high	DS	Brown	0.90
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
6	[I, M, M, F, M, S]	average	DS	John	0.70
7	[I, M, R, M, S]	high	SE	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60
9	[I, M, F, R, S]	high	SE	Brown	0.80

Example

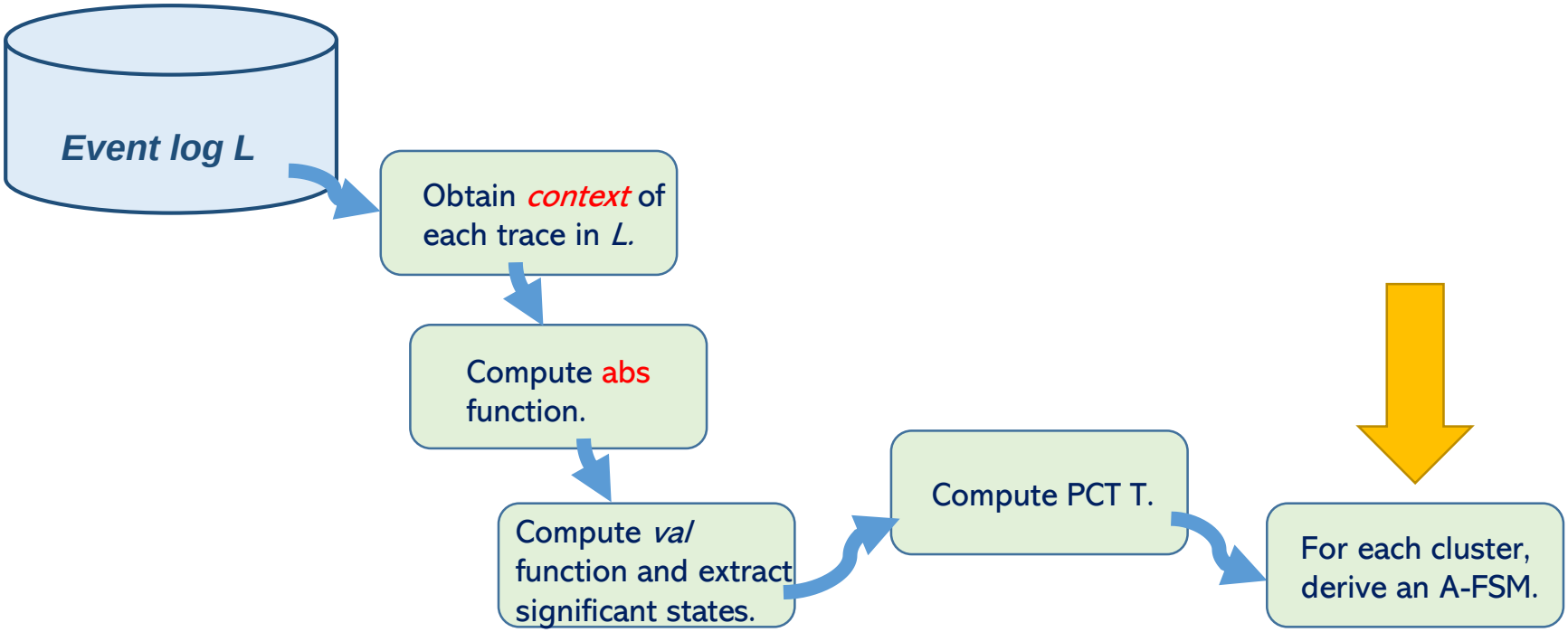
the process of preparation and supervision of an academic research paper

Clustering function given by the PCT:



CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
1	[I, M, M, F, R, S]	high	DS	John	0.85
2	[I, M, M, F, R, S]	high	DS	John	0.95
3	[I, M, M, R, F, S]	high	DS	Brown	0.90
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
6	[I, M, M, F, M, S]	average	DS	John	0.70
7	[I, M, R, M, S]	high	SE	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60
9	[I, M, F, R, S]	high	SE	Brown	0.80

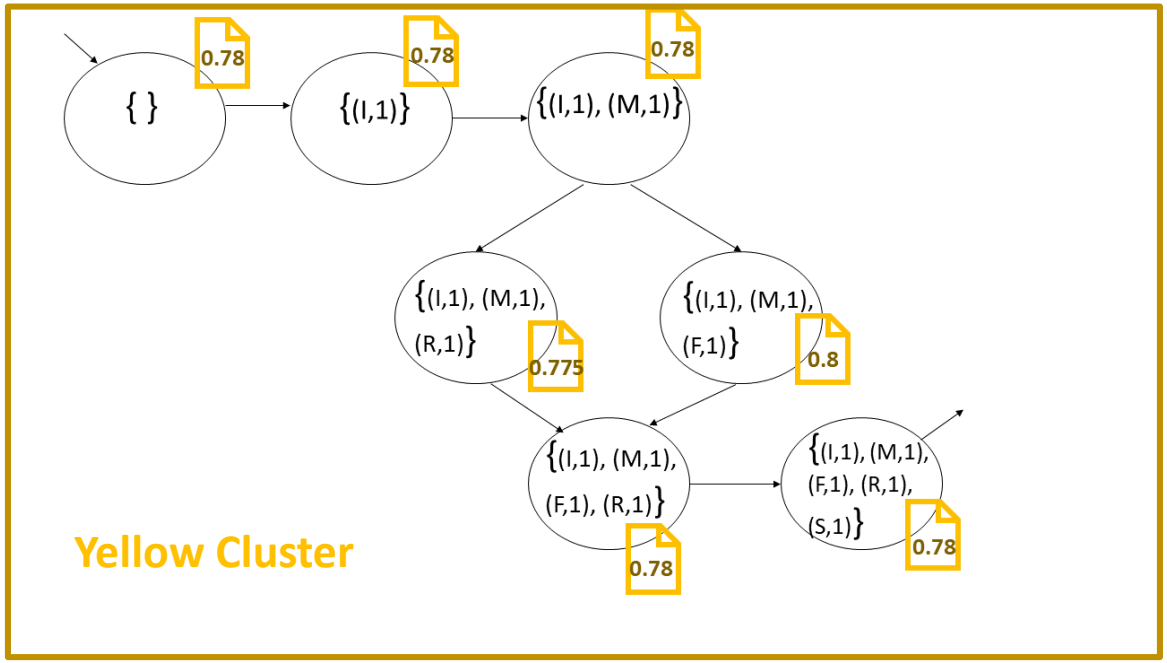
Approach - Overview



Example

the process of preparation and supervision of an academic research paper

CaseID	Trace	PK	Field	Supervisor	Final Grade
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
9	[I, M, F, R, S]	high	SE	Brown	0.80



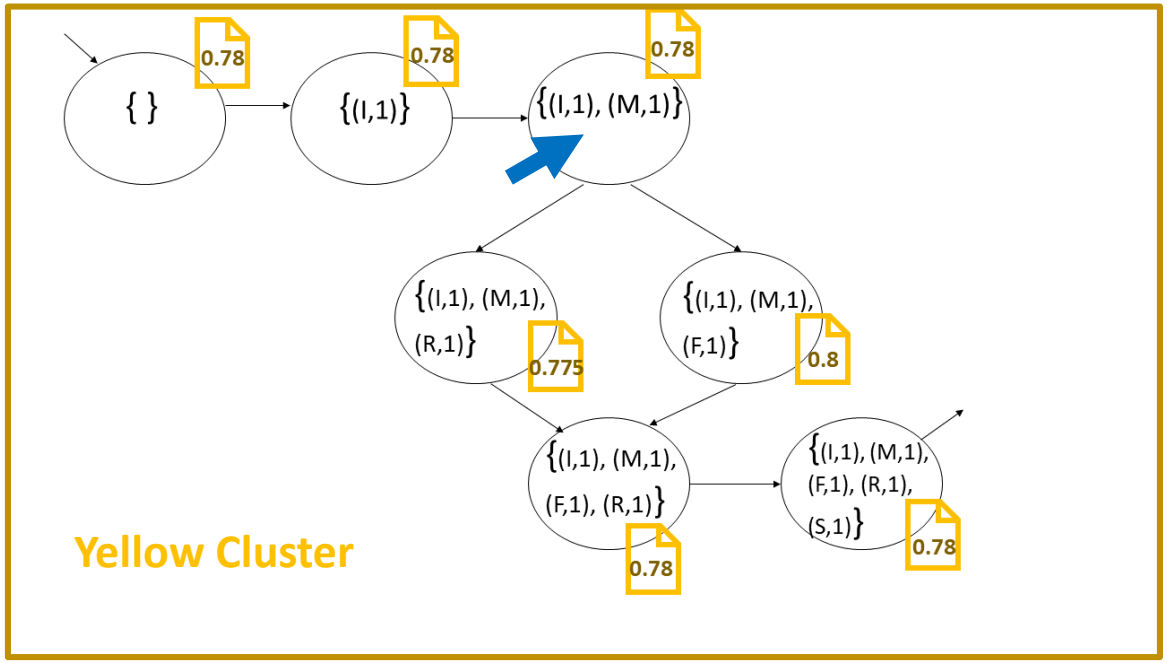
Example

the process of preparation and supervision of an academic research paper

CaseID	Trace	PK	Field	Supervisor	Final Grade
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
9	[I, M, F, R, S]	high	SE	Brown	0.80

New case with this Field and this Supervisor:

<I, M,...>



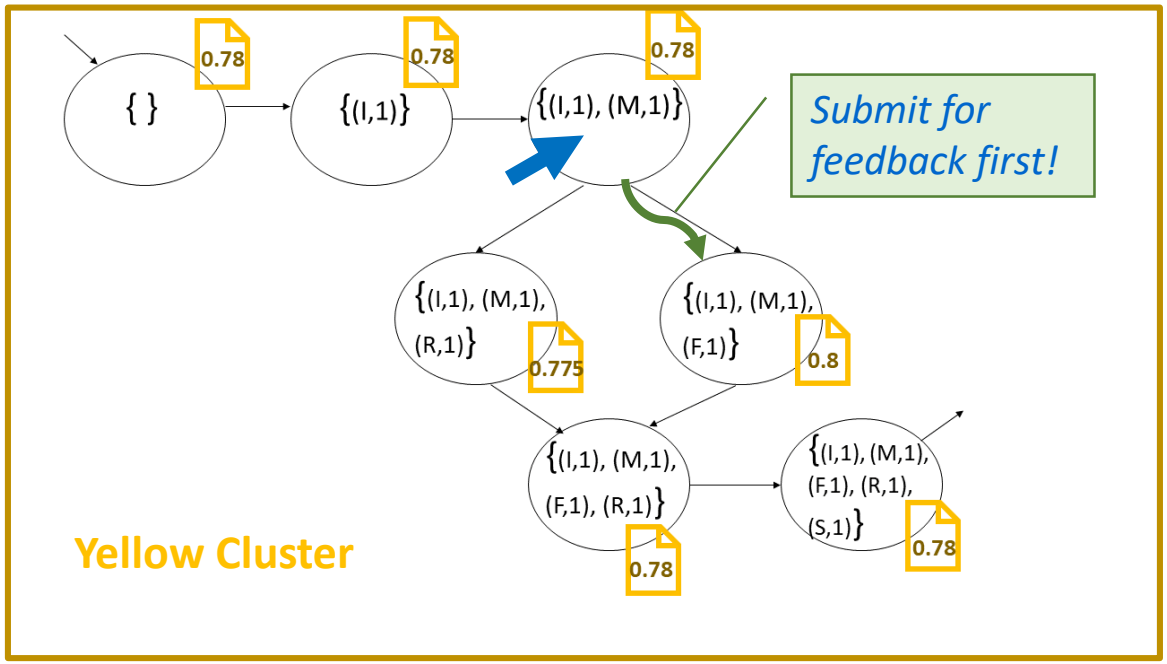
Example

the process of preparation and supervision of an academic research paper

CaseID	Trace	PK	Field	Supervisor	Final Grade
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
9	[I, M, F, R, S]	high	SE	Brown	0.80

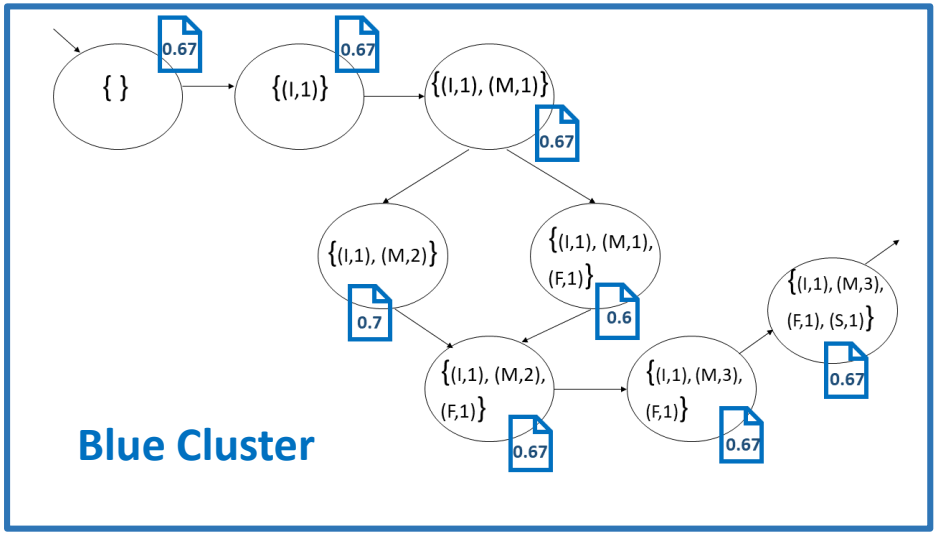
New case with this Field and this Supervisor:

<I, M,...>



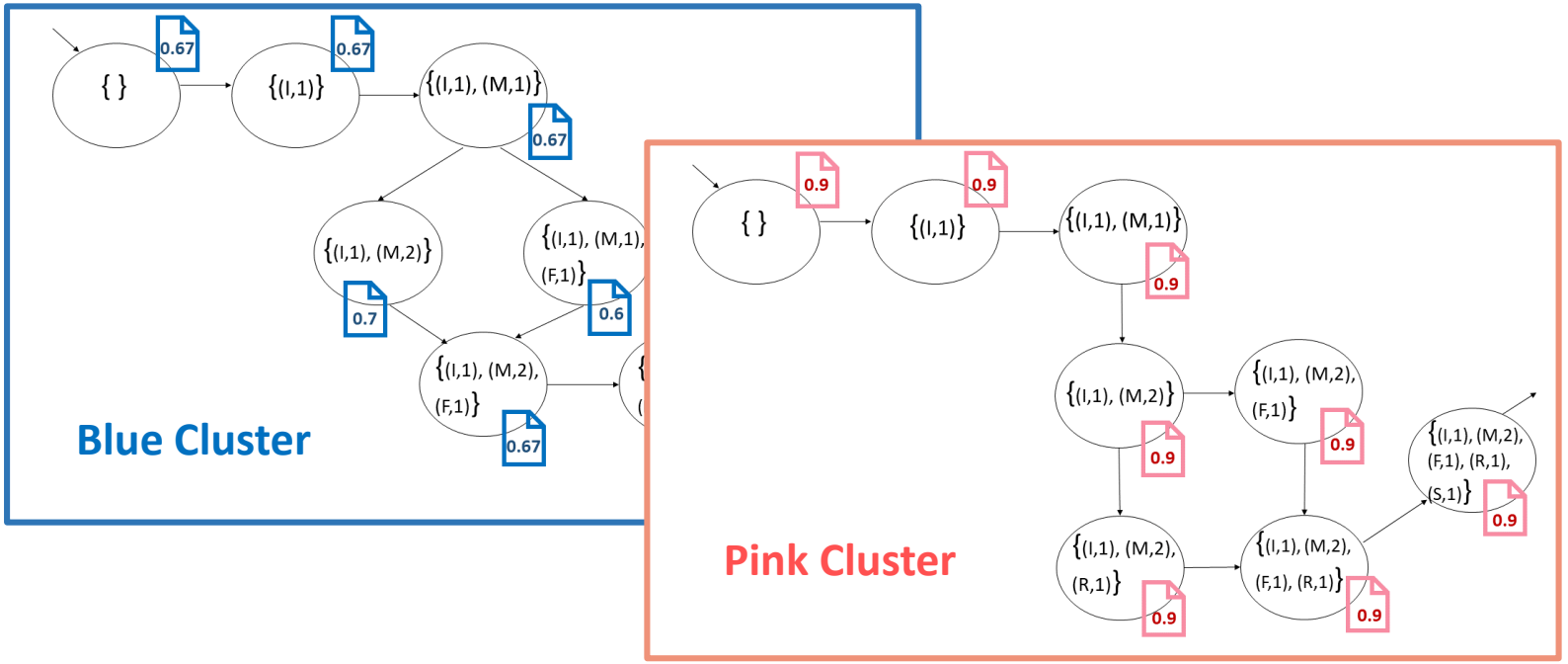
Example

the process of preparation and supervision of an academic research paper



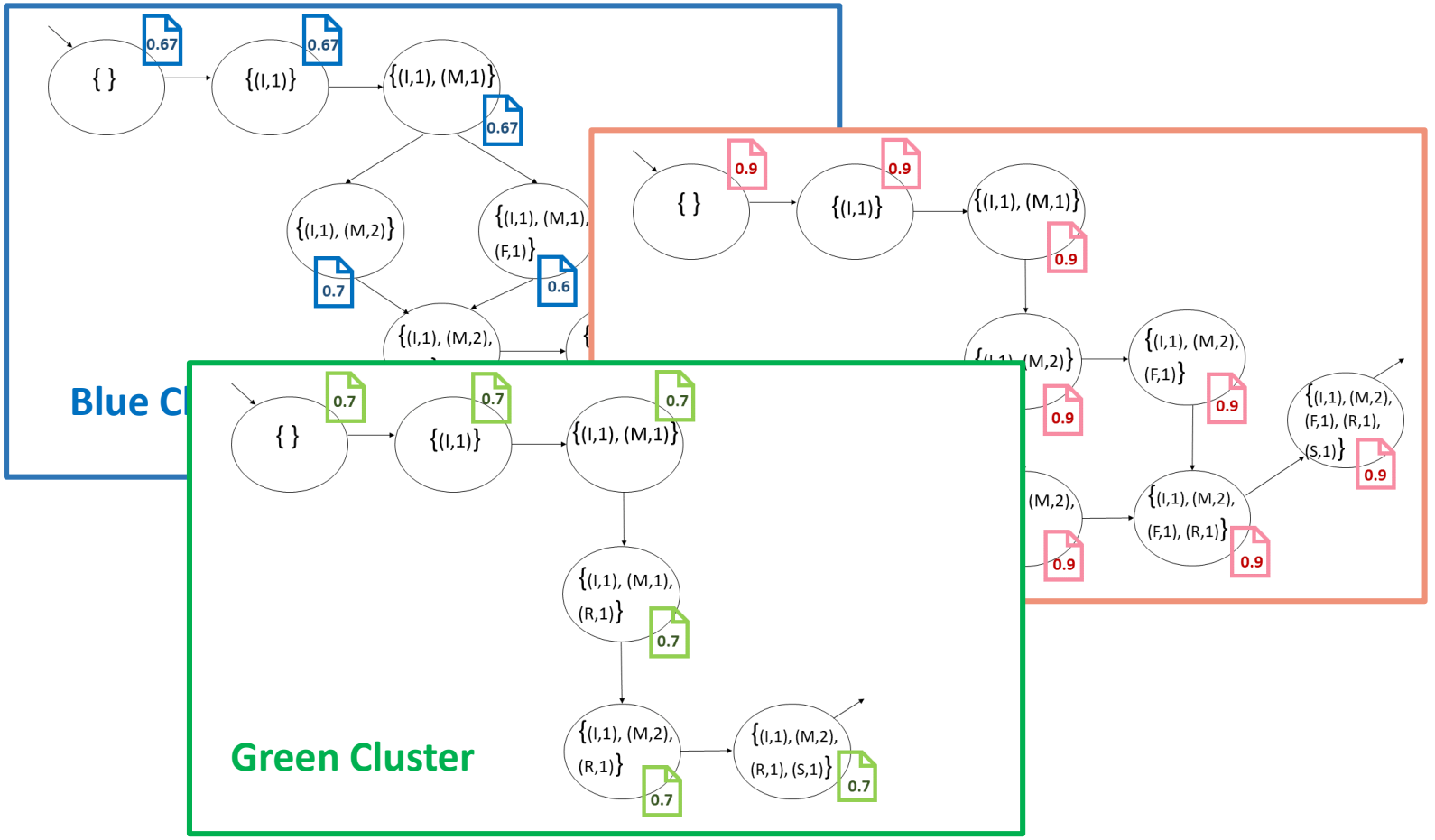
Example

the process of preparation and supervision of an academic research paper



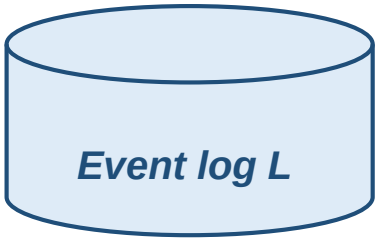
Example

the process of preparation and supervision of an academic research paper



Example (predicting both RT and final grade)

the process of preparation and supervision of an academic research paper



Case dependent External

CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
1	[I, M, M, F, R, S]	high	DS	John	0.85
2	[I, M, M, F, R, S]	high	DS	John	0.95
3	[I, M, M, R, F, S]	high	DS	Brown	0.90
4	[I, M, R, F, S]	average	SE	Brown	0.80
5	[I, M, R, F, S]	high	SE	Brown	0.75
6	[I, M, M, F, M, S]	average	DS	John	0.70
7	[I, M, R, M, S]	high	SE	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60
9	[I, M, F, R, S]	high	SE	Brown	0.80

I : Introductory meeting
M: Meeting with the supervisor
F: Feedback
R: Presentation rehearsal
S: Submission

PK : Prior Knowledge

Predict remaining time, final grade

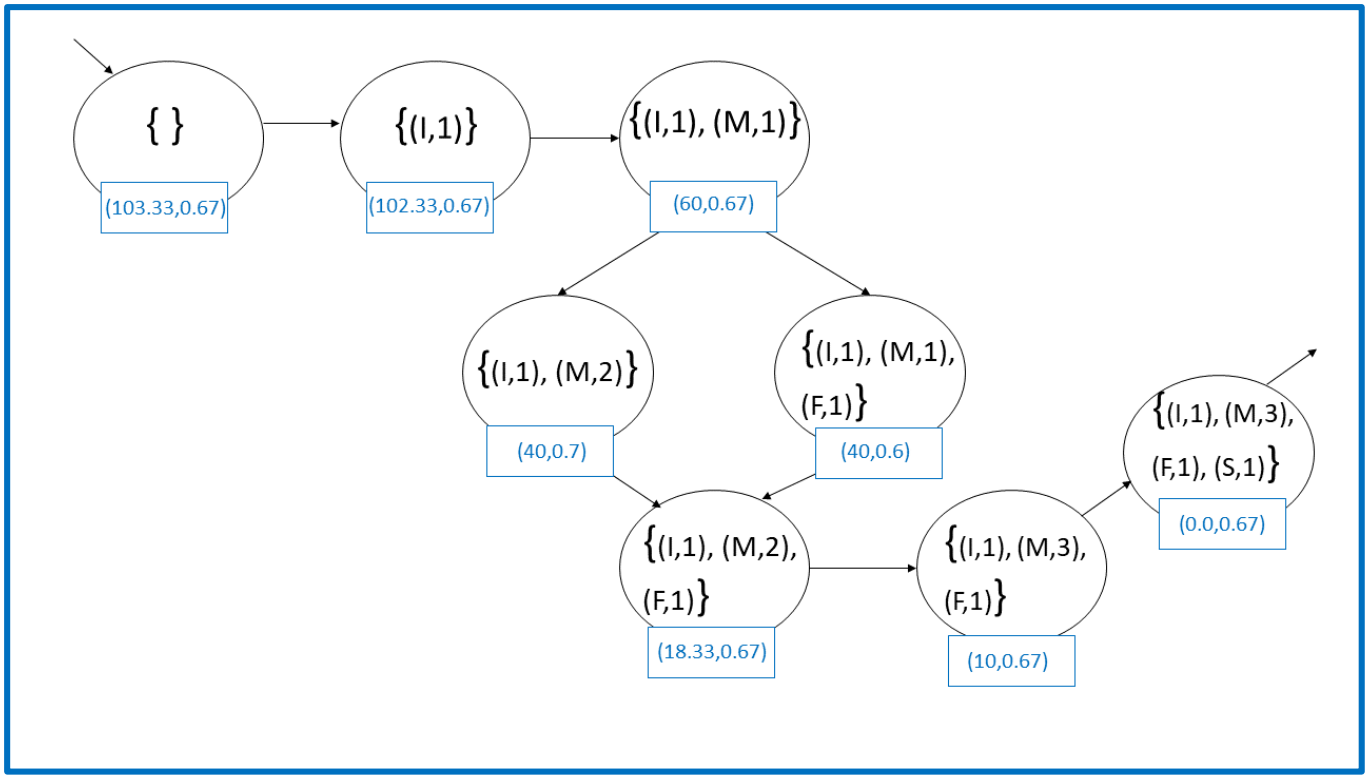
abs: multiset

Example (predicting both RT and final grade)

the process of preparation and supervision of an academic research paper

CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
6	[I, M, M, F, M, S]	average	DS	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60

A-FSM for the Blue cluster :

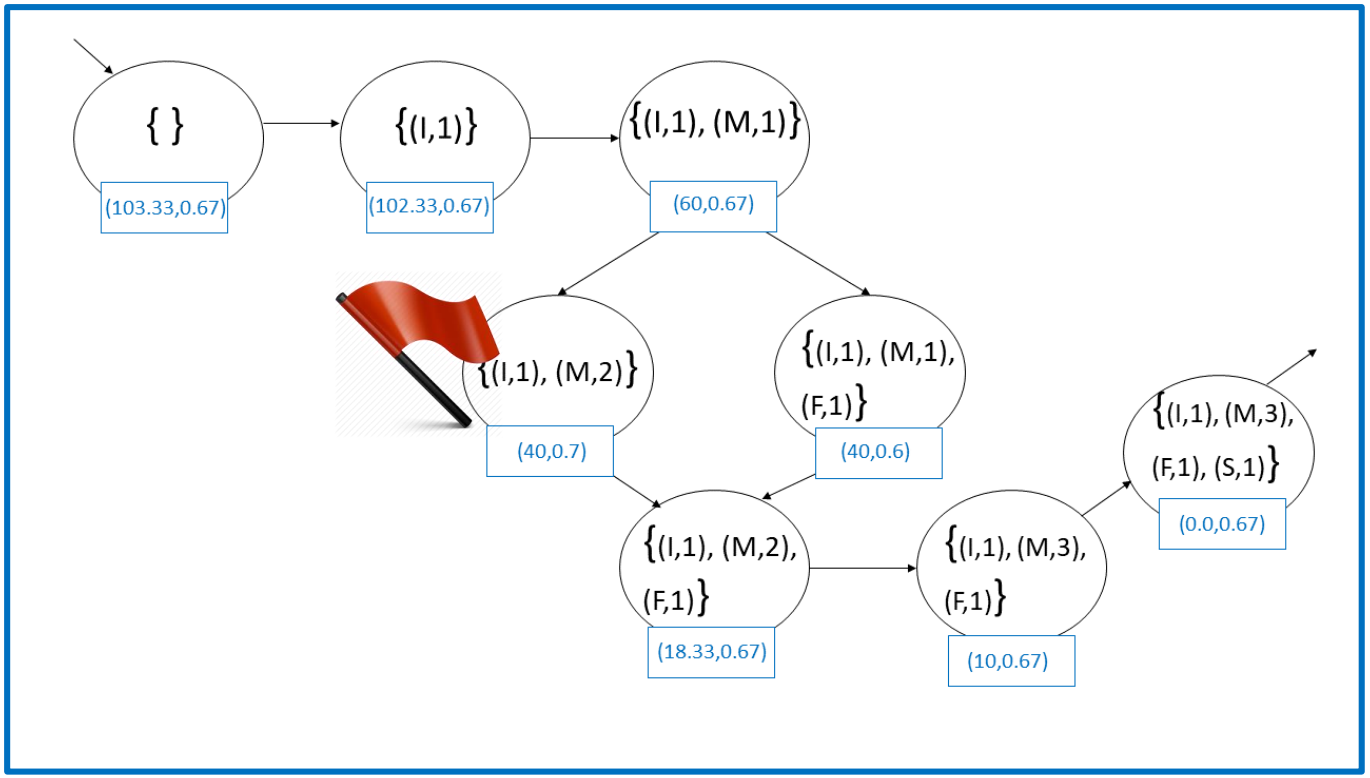


Example (predicting both RT and final grade)

the process of preparation and supervision of an academic research paper

CaseID	Trace	PK	Field	Supervisor	Final Grade
0	[I, M, M, F, M, S]	average	SE	John	0.70
6	[I, M, M, F, M, S]	average	DS	John	0.70
8	[I, M, F, M, M, S]	average	DS	John	0.60

A-FSM for the Blue cluster :



Further possibilities

Until now:

- always used the activity labels for representing traces.
- always picked a simple abstraction function
- always used the average measure to estimate the annotations

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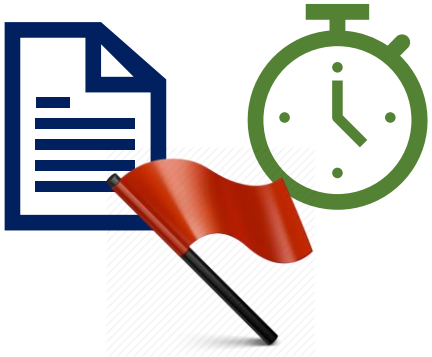

Additionally:

Complement the annotations of the states with comments, warnings or suggestions about future actions

Questions?

Thank you for your attention.

Literature

- [1] Francesco Folino, Masssimo Guarascio, Luigi Pontieri.: Discovering Context-Aware Models for Predicting Business Process Performances. Institute for High Performance Computing and Networking (ICAR). R. Meersman et al. (Eds.): OTM 2012, Part I, LNCS 7565, pp.287-304, 2012.

- [2] van der Aalst, W.M.P., Schonenberg, M.H., Song, M.: Time prediction based on process mining. Information Systems 36(2), 450-475 (2011).

- [3] Blockeel, H., Raedt, L.D., Ramon, J.: Top-down induction of clustering trees. In: Proc. of 15th Intl. Conference on Machine Learning (ICML1998). pp. 55-63 (1998).