Lab for the course on Process and Service Modeling and Analysis

LAB-07

Declarative Process Modeling and Mining

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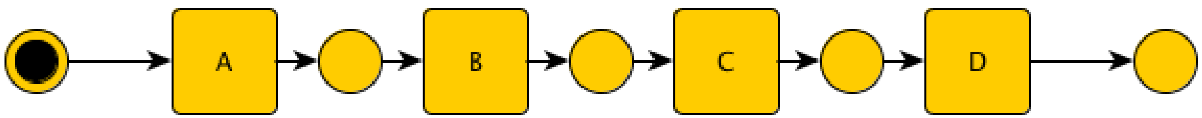
Courtesy of Fabrizio Maria Maggi and Claudio Di Ciccio

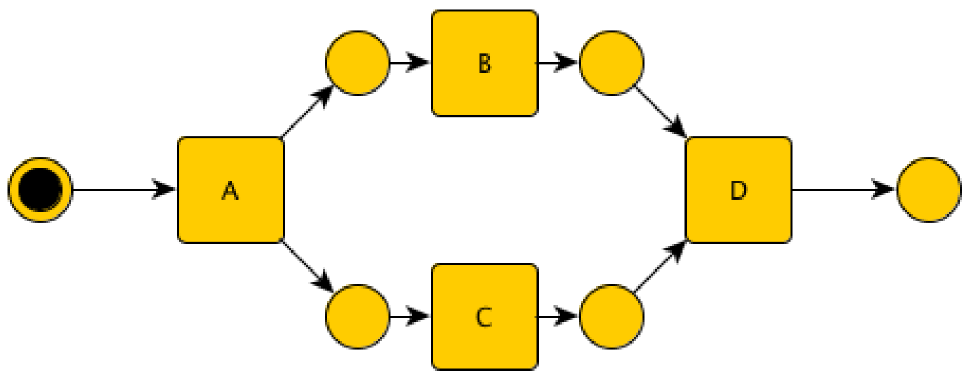
Outline

- Imperative vs Declarative process modelling
- Declarative process modeling with **DECLARE**
- Instantiation of declarative constraints through **DECLARE templates**
- Declarative Process Mining in ProM
- Classroom Exercises

Imperative Process Models

- An imperative process model represents the whole process behaviour **at once**.
  - The most used notation is based on a subclass of Petri Nets (namely, the ***Workflow Nets***). Other extension exist (e.g., ***BPMN***).

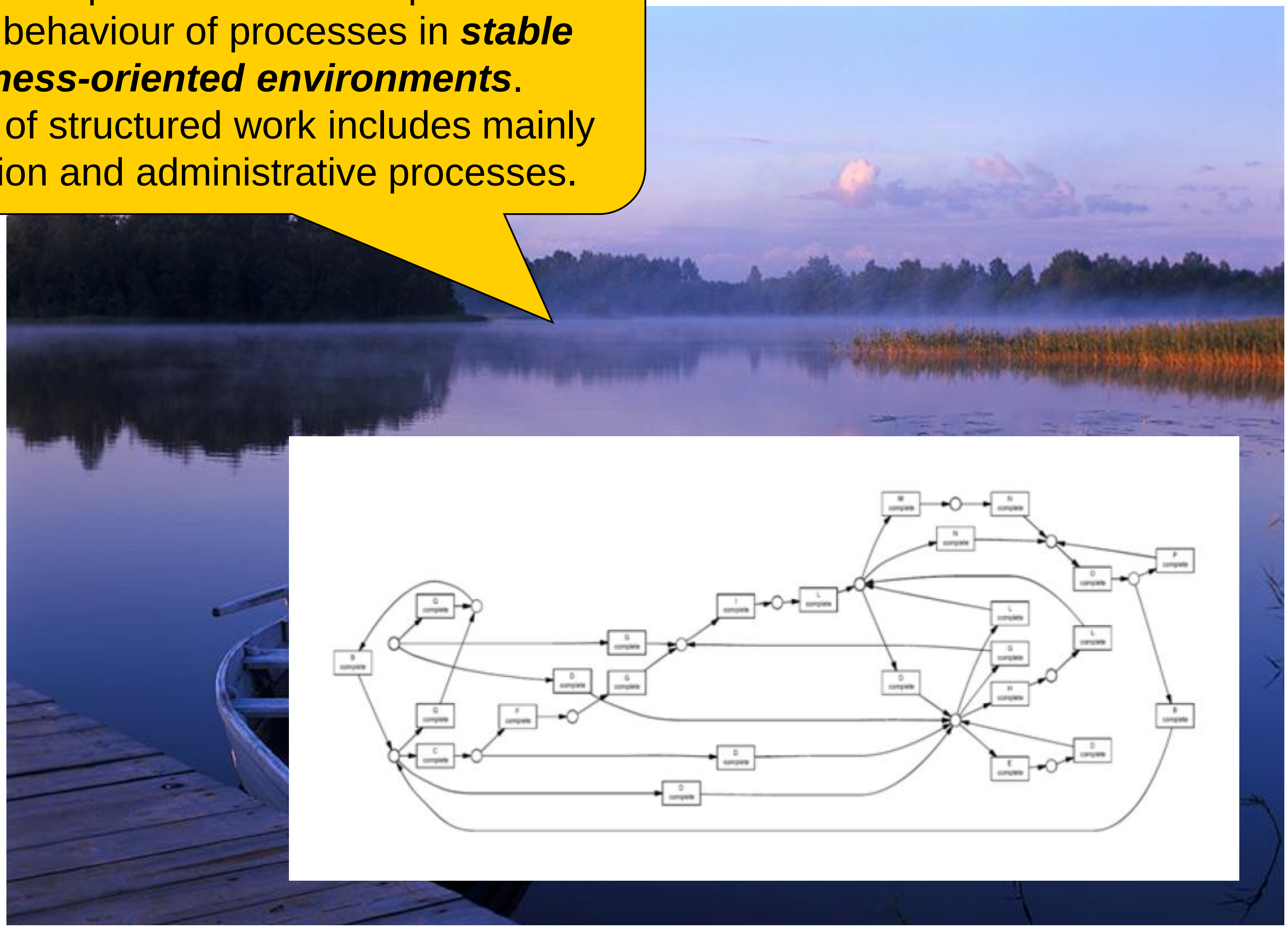




Imperative process models ***explicitly specify* all possible behaviors** (**closed models**).

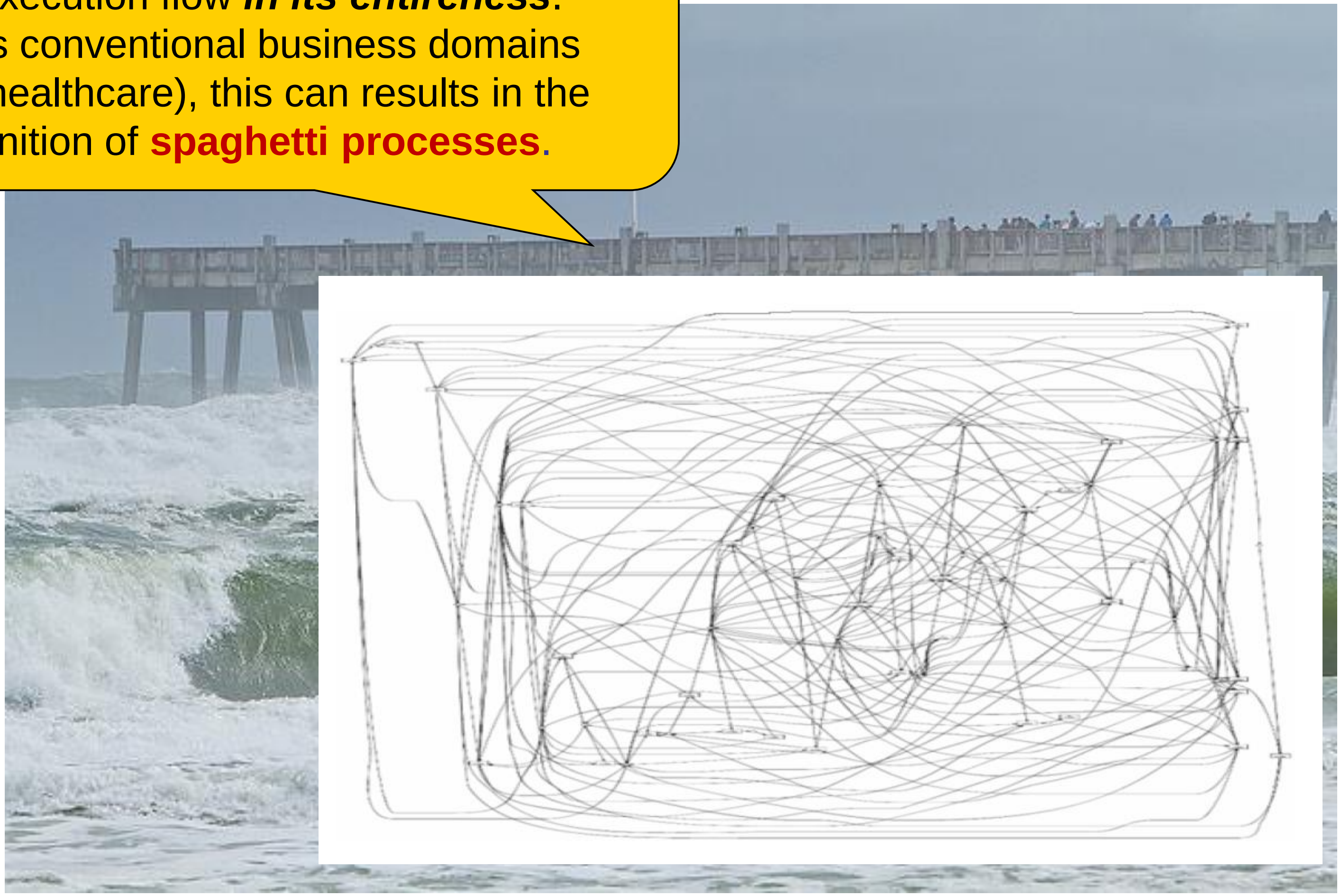
Imperative Process Models in Stable Environments

Imperative process models represent well the behaviour of processes in ***stable business-oriented environments***.
This kind of structured work includes mainly production and administrative processes.



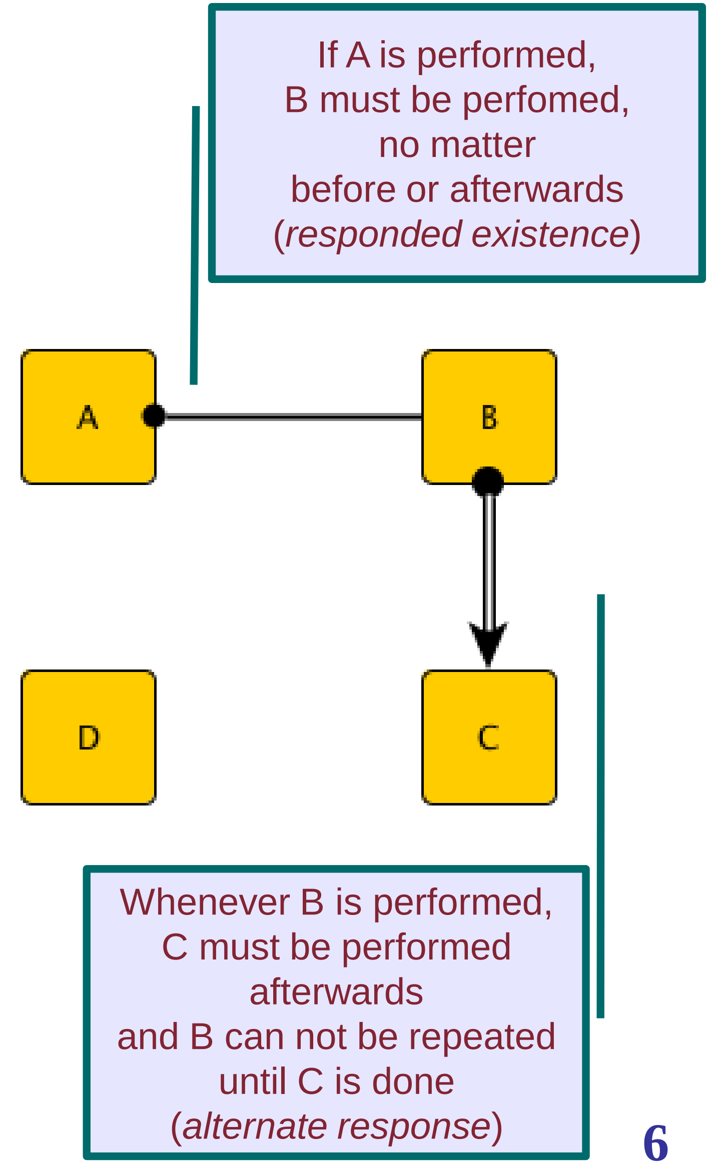
Imperative Process Models in Turbulent Environments

Imperative process models prescribe the execution flow ***in its entireness***.
In less conventional business domains (e.g., healthcare), this can results in the definition of **spaghetti processes**.



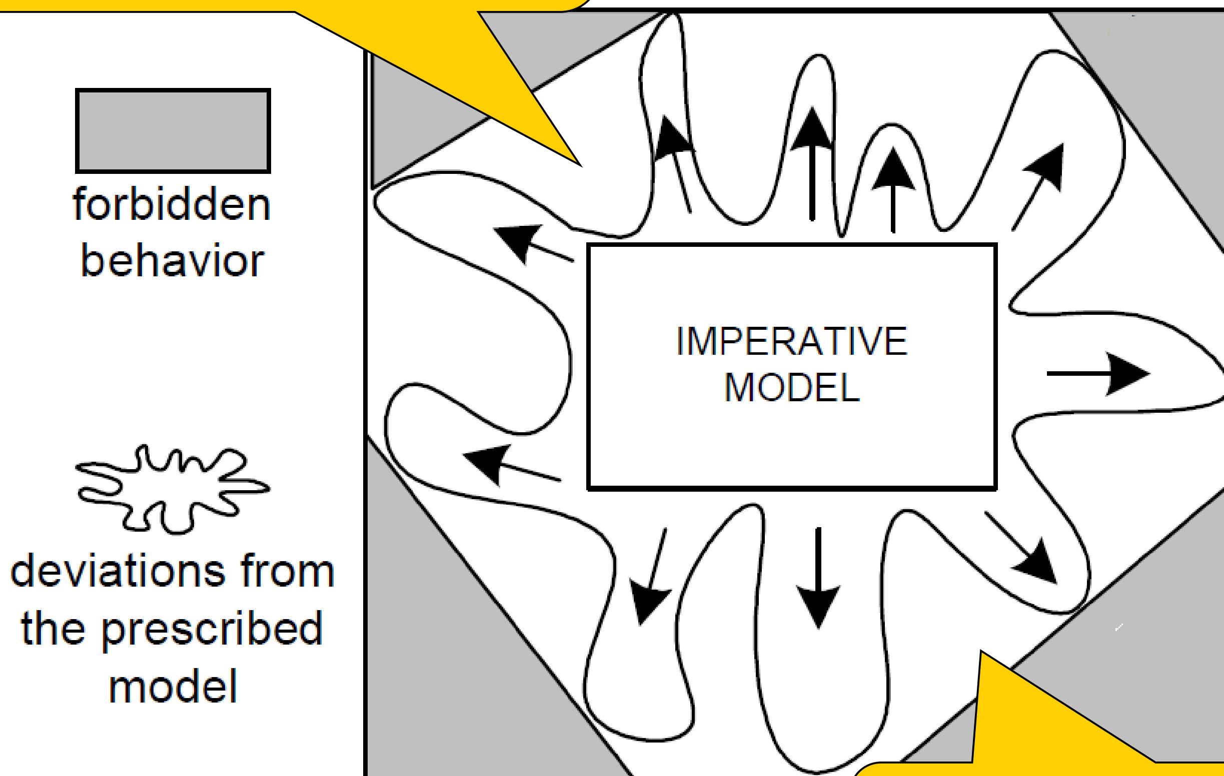
Declarative Process Models

- Rather than using an imperative language for expressing the allowed sequence of activities, **declarative process models** are based on the description of business processes through the usage of **constraints**.
- Such contraints **implicitly specify** the **allowed behaviour** of the process.
- The idea is that **every task can be performed**, **except the ones** which do not respect such constraints.
- Declarative models are appropriate to describe **dynamic environments**, where processes are highly flexible and subject to changes.



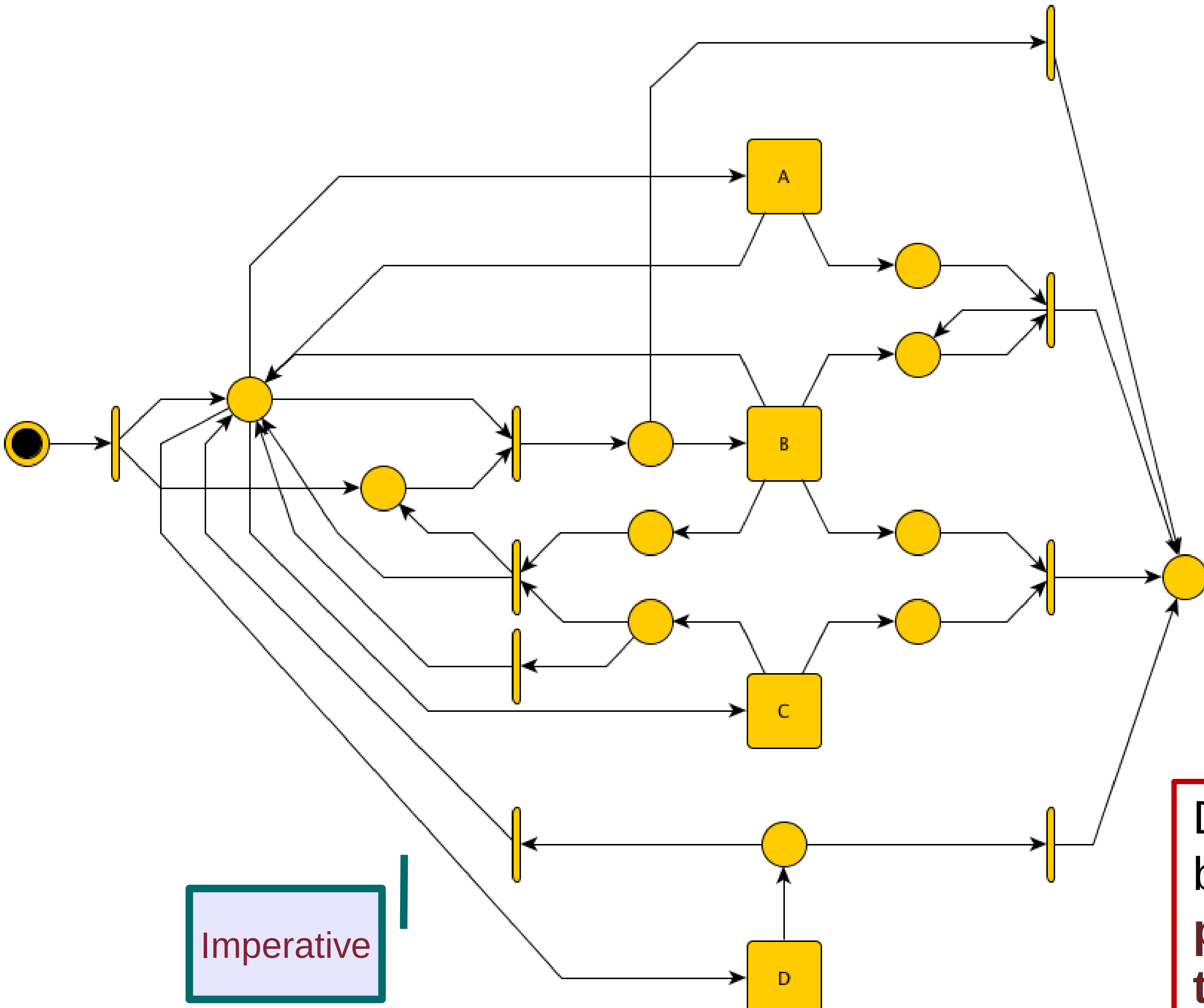
Imperative vs Declarative Models

Imperative process models ***explicitly specify*** all possible sequences of activities in a process.

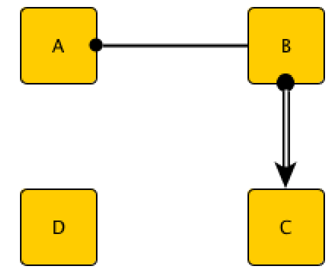


Declarative process models offer **more flexibility:** ***everything that is not specified is allowed***.

Imperative vs Declarative Models



Imperative



Declarative

Declarative models work better in presence of a **partial specification of the process scheme.**

The DECLARE Process Modeling Language

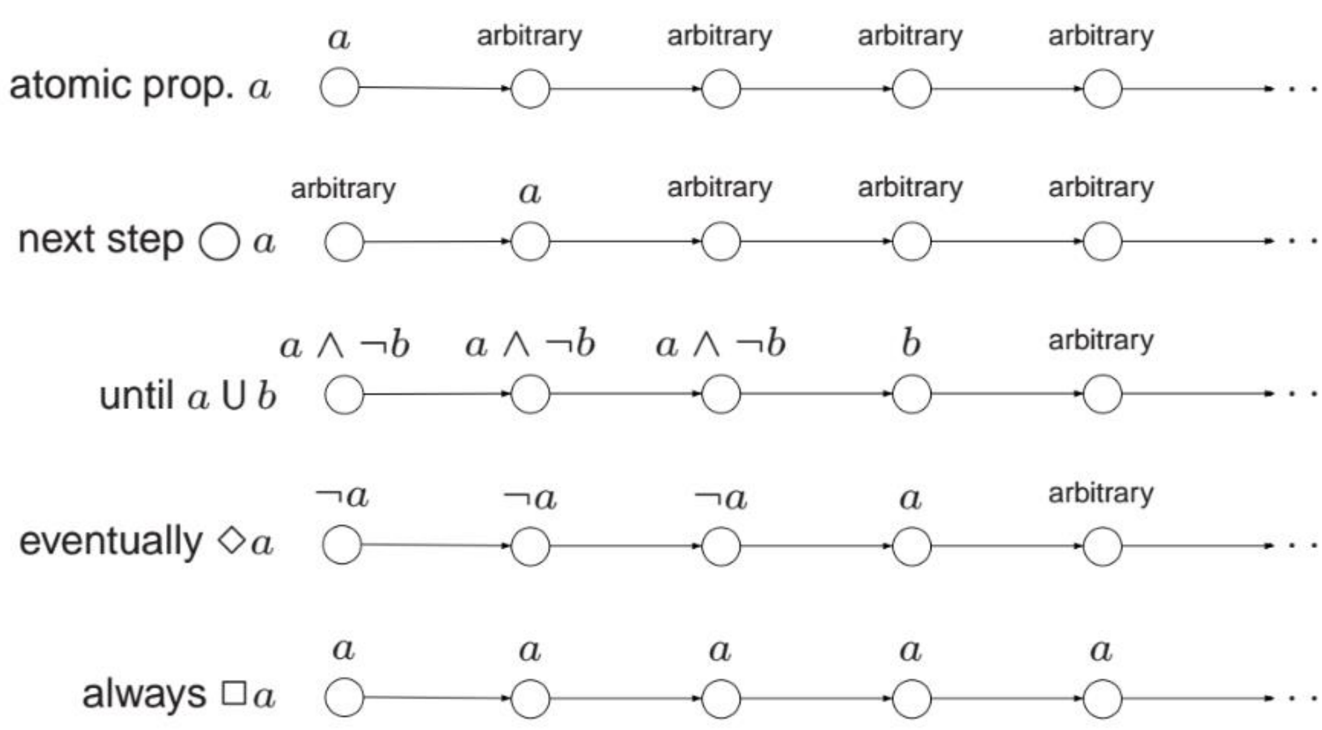
- DECLARE is a declarative process modeling language originally introduced in:

> Wil MP van Der Aalst, Maja Pesic, Helen Schonenberg
> ***Declarative workflows: Balancing between flexibility and support***
> Computer Science-Research and Development vol.23, n.2 (2009)

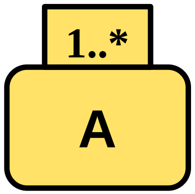
- Technically a DECLARE model $D = (A, \pi_D)$ consists of a set of possible activities A involved in a process and a collection of ***temporal constraints*** π_D defined over such activities.
- DECLARE constraints are instantiation of ***templates***, i.e., patterns that define parameterized classes of properties.
- Templates have a ***graphical representation*** and enjoy a precise semantics in ***LTL over finite traces.***

Recap: LTL Operator Semantics

operator	*semantics*
$\bigcirc\varphi$	φ *has to hold in the next position of a path.*
$\Box\varphi$	φ *has to hold always in the subsequent positions of a path.*
$\Diamond\varphi$	φ *has to hold eventually (somewhere) in the subsequent positions of a path.*
$\varphi\, U\, \psi$	φ *has to hold in a path at least until* ψ *holds.* ψ *must hold in the current or in a future position.*
$\varphi\, W\, \psi$	φ *has to hold in the subsequent positions of the log at least until* ψ *holds. If* ψ *never holds,* φ *must hold everywhere.*



Existence templates

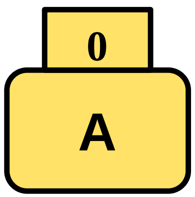


Existence(A)

LTL Formalization: $\Diamond \mathbf{A}$

Activity *A* occurs at least 1 time in the process instance.

BCAAC ✓ *BCAAAC* ✓ *BCC* ✗

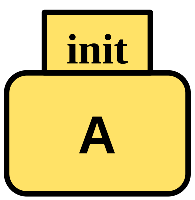


Absence(A)

LTL Formalization: $\neg \Diamond \mathbf{A}$

Activity *A* does not occur in the process instance.

BCC ✓ *BCAC* ✗

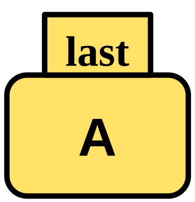


Init(A)

LTL Formalization: $\mathbf{A}$

Activity A is the first to occur in each process instance.

BCAAC ✗ *ACAAAC* ✓ *BCC* ✗



Last(A)

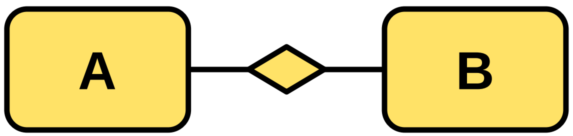
LTL Formalization: $\Diamond(\mathbf{A} \wedge \bigcirc \neg T)$

Activity A is the last to occur in each process instance.

BCAAC ✗ *ACAAAC* ✗ *BCA* ✓

DECLARE constraint templates

Choice templates

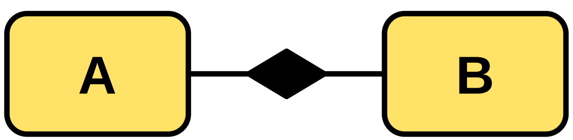


Choice(A,B)

LTL Formalization: $\Diamond \mathbf{A} \lor \Diamond \mathbf{B}$

Activity *A* or *B* *eventually occur* in the process instance.

BCAAC ✓ *CDC* ✗ *BCC* ✓



Exclusive Choice(A,B)

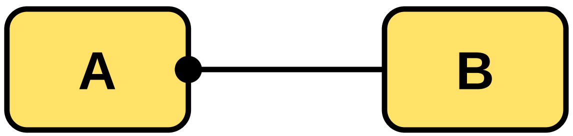
LTL Formalization: $(\Diamond \mathbf{A} \lor \Diamond \mathbf{B}) \land \neg(\Diamond \mathbf{A} \land \Diamond \mathbf{B})$

Activity *A* or *B* *eventually occur* in the process instance, but not together.

BCAAC ✗ *CDC* ✗ *BCC* ✓

DECLARE constraint templates

Relation templates

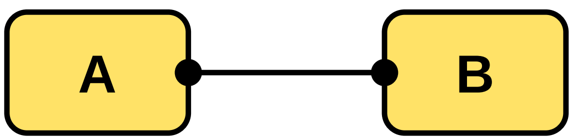


RespondedExistence(A, B)

LTL Formalization: $\Diamond \mathbf{A} \rightarrow \Diamond \mathbf{B}$

If *A* occurs in the process instance, then *B* occurs as well.

CAC ✗ *CAACB* ✓ *BCAC* ✓ *BCC* ✓



Co-Existence

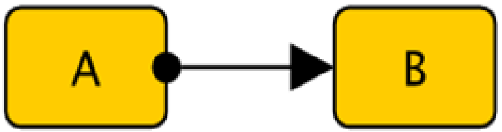
LTL Formalization: $(\Diamond \mathbf{A} \rightarrow \Diamond \mathbf{B}) \wedge (\Diamond \mathbf{B} \rightarrow \Diamond \mathbf{A})$

Activity *A* or *B eventually occur* in the process instance.

BCAAC ✓ *CDC* ✗ *BCC* ✗

DECLARE constraint templates

Relation templates

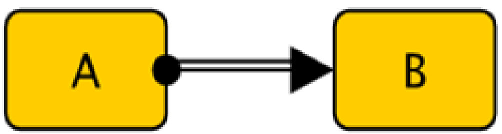


Response(A, B)

LTL Formalization: $\Box (A \rightarrow \Diamond B)$

If *A* occurs in the process instance, then *B* occurs after *A*.

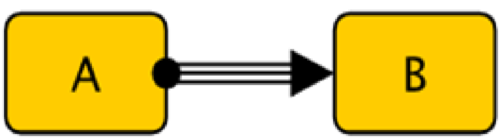
BCAAC ✗ *CAACB* ✓ *CAC* ✗ *BCC* ✓



AlternateResponse(A, B)

LTL Formalization: $\Box (A \rightarrow \bigcirc(\neg A \; \mathcal{U} \; B))$

Each time *A* occurs in the process instance, then *B* occurs afterwards, before *A* recurs. *BCAAC* ✗ *CAACB* ✗ *CACB* ✓ *CABCA* ✗ *BCC* ✓ *CACBBAB* ✓



ChainResponse(A, B)

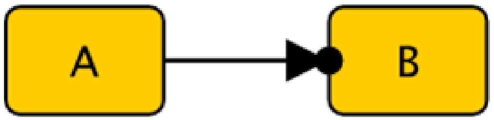
LTL Formalization: $\Box (A \rightarrow \bigcirc B)$

Each time *A* occurs in the process instance, then *B* occurs immediately afterwards.

BCAAC ✗ *BCAABC* ✗ *BCABABC* ✓

DECLARE constraint templates

Relation templates

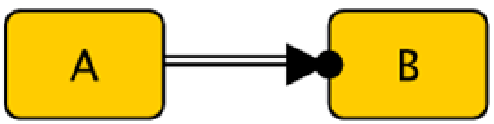


Precedence(A,B)

LTL Formalization: $\neg \mathbf{B} \; W \; \mathbf{A}$

B occurs in the process instance only if preceded by *A*

BCAAC ✗ *CAACB* ✓ *CAC* ✓

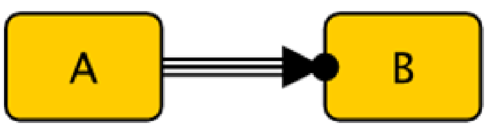


AlternatePrecedence(A,B)

LTL Formalization: $(\neg \mathbf{B} \; W \; \mathbf{A}) \wedge \Box (\mathbf{B} \rightarrow (\neg \mathbf{B} \; W \; \mathbf{A}))$

Each time *B* occurs in the process instance, it is preceded by *A* and no other *B* can recur in between. *BCC* ✗

BCAAC ✗ *CAACB* ✓ *CACB* ✓ *CABCA* ✓ *CACBAB* ✓



ChainPrecedence(A,B)

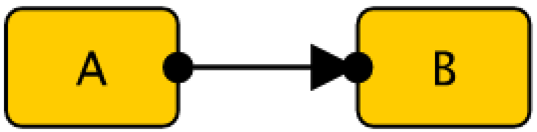
LTL Formalization: $\Box (\mathrm{O}\mathbf{B} \rightarrow \mathbf{A})$

Each time *B* occurs in the process instance, then *A* occurs immediately beforehand

BCAAC ✗ *BCAABC* ✗ *CABABCA* ✓

DECLARE constraint templates

Relation templates

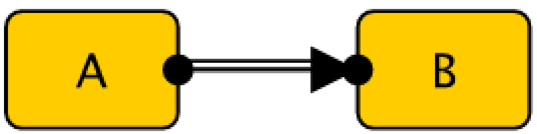


Succession(A, B)

LTL Formalization: $\square\,(\mathbf{A}\rightarrow\lozenge\mathbf{B}) \wedge (\neg\mathbf{B}\ \mathcal{W}\ \mathbf{A})$

A (*B*) occurs if and only if it is followed (preceded) by *B* (*A*) in the process instance

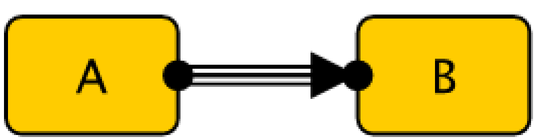
BCAAC ✗ *CAACB* ✓ *CAC* ✗ BCC ✗ CDC ✓



AlternateSuccession(A,B)

LTL Formalization: $\square\,(\mathbf{A}\rightarrow\bigcirc(\neg\mathbf{A}\ \mathcal{U}\ \mathbf{B})) \wedge (\neg\mathbf{B}\ \mathcal{W}\ \mathbf{A}) \wedge \square\,(\mathbf{B}\rightarrow(\neg\mathbf{B}\ \mathcal{W}\ \mathbf{A})))$

A and *B* occur in the process instance if and only if the latter follows the former, and they alternate each other in the trace. *BCAAC* ✗ *CAACB* ✗ *CACB* ✓ *CABCA* ✗ *BCC* ✗ *CACBAB* ✓



ChainSuccession(A,B)

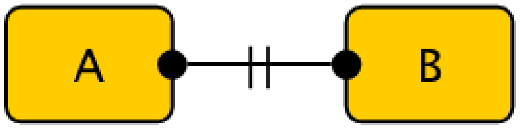
LTL Formalization: $\square(\mathbf{A}\rightarrow\bigcirc\mathbf{B}) \wedge \square(\bigcirc\mathbf{A}\rightarrow\mathbf{B})$

A and *B* occur in the process instance if and only if the latter immediately follows the former

BCAAC ✗ *BCAABC* ✗ *CABABC* ✓

DECLARE constraint templates

Relation templates

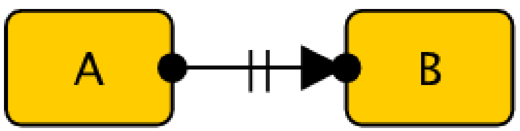


NotCoExistence(A,B)

LTL Formalization: $(\Diamond \mathbf{A} \rightarrow \neg \Diamond \mathbf{B}) \land (\Diamond \mathbf{B} \rightarrow \neg \Diamond \mathbf{A})$

A and *B* never occur together in the process instance

CAC ✓ *CAACB* ✗ *BCAC* ✗ *BCC* ✓ *CDC* ✓

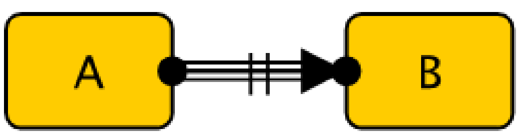


NotSuccession(A,B)

LTL Formalization: $\Box (\mathbf{A} \rightarrow \neg \Diamond \mathbf{B})$

A can never occur before *B* in the process instance

BCAAC ✓ *CAACB* ✗ *CAC* ✓ *BCC* ✓



NotChainSuccession(A,B)

LTL Formalization: $\Box (\mathbf{A} \rightarrow \neg \bigcirc \mathbf{B})$

A and *B* occur in the process instance if and only if the latter does not immediately follows the former

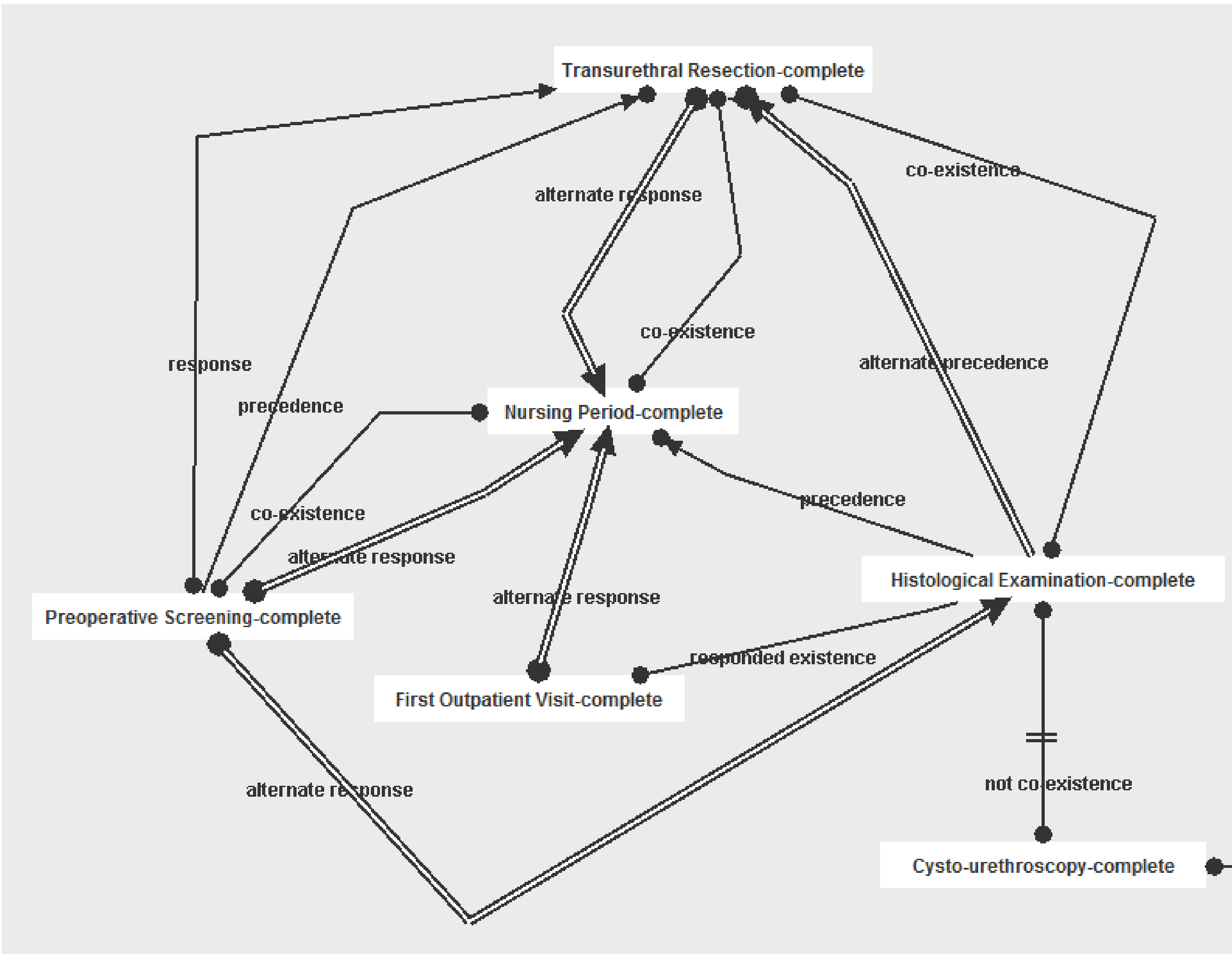
BCAAC ✓ *BCAABC* ✗ *CBACBA* ✓

The DECLARE System

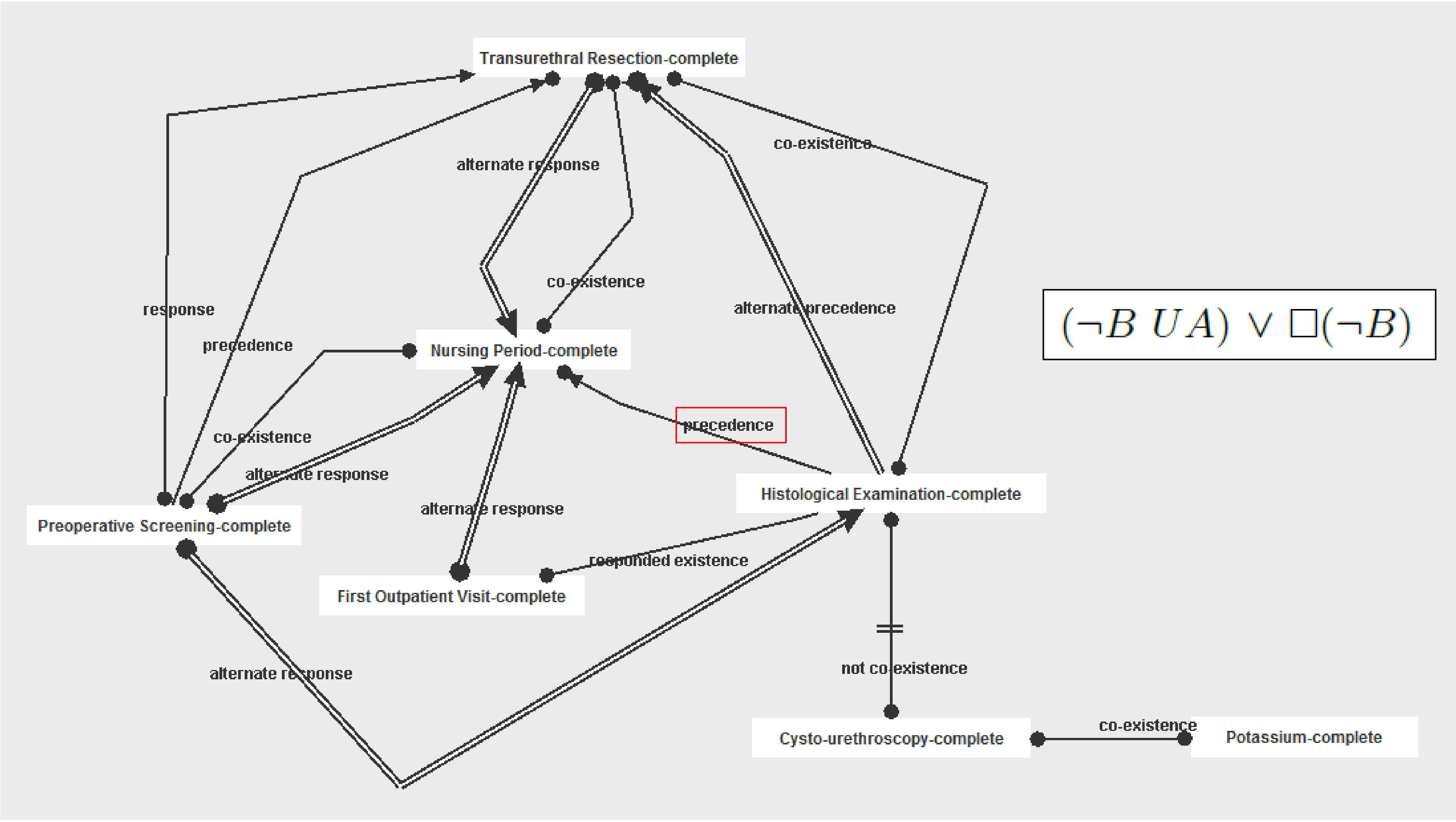
- The **DECLARE System** consists of the Designer, the Framework, and the Worklist.
  - The ***DECLARE Designer*** consists of a graphical editor component for creating and verifying DECLARE models.
  - The ***DECLARE Framework*** works as the backend server for executing DECLARE processes.
  - The ***DECLARE Worklist*** is the user client connecting to the Framework.
- The DECLARE System can be downloaded from:

http://www.win.tue.nl/declare/download/

An Example of DECLARE Model

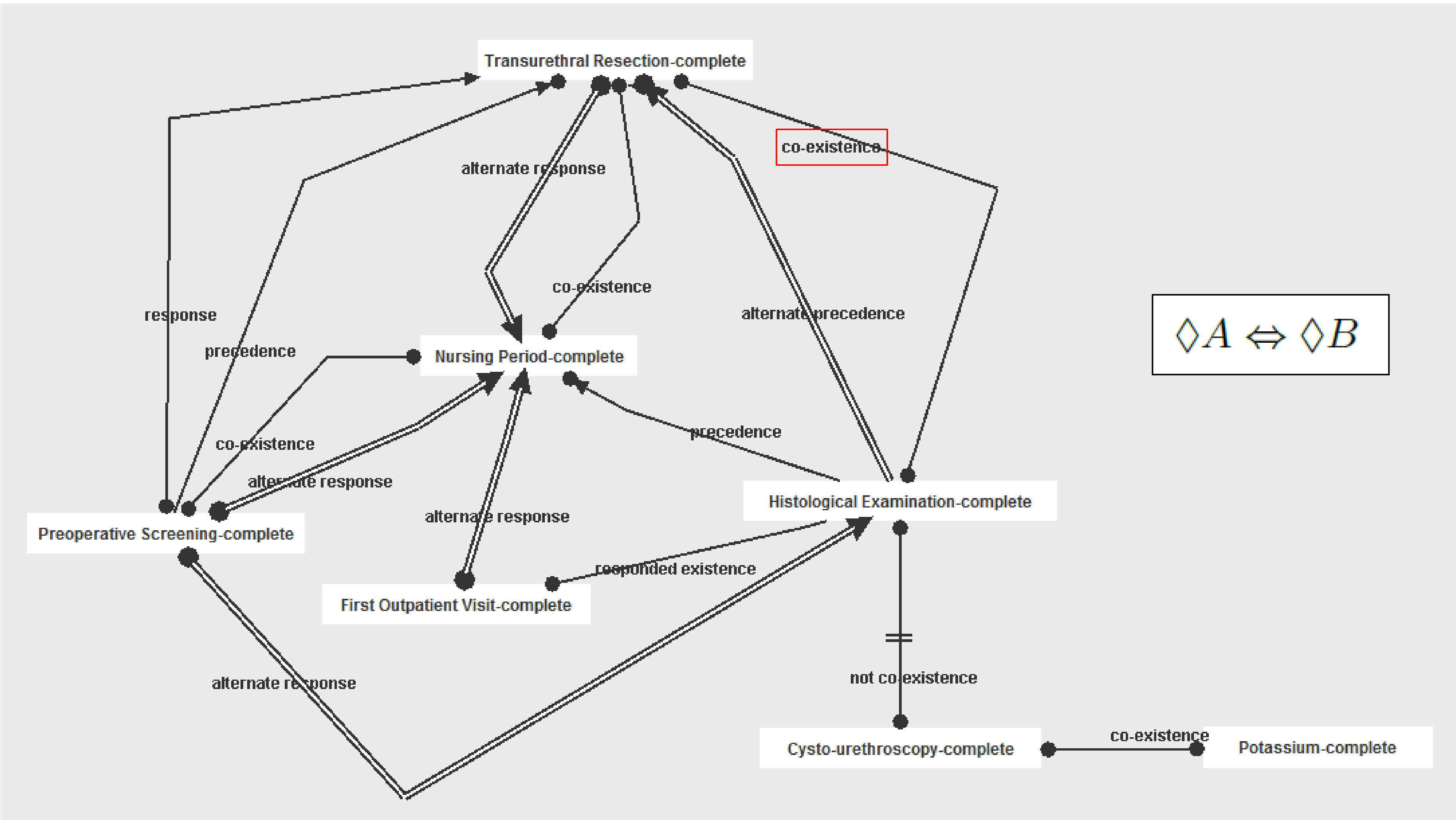


An Example of DECLARE Model



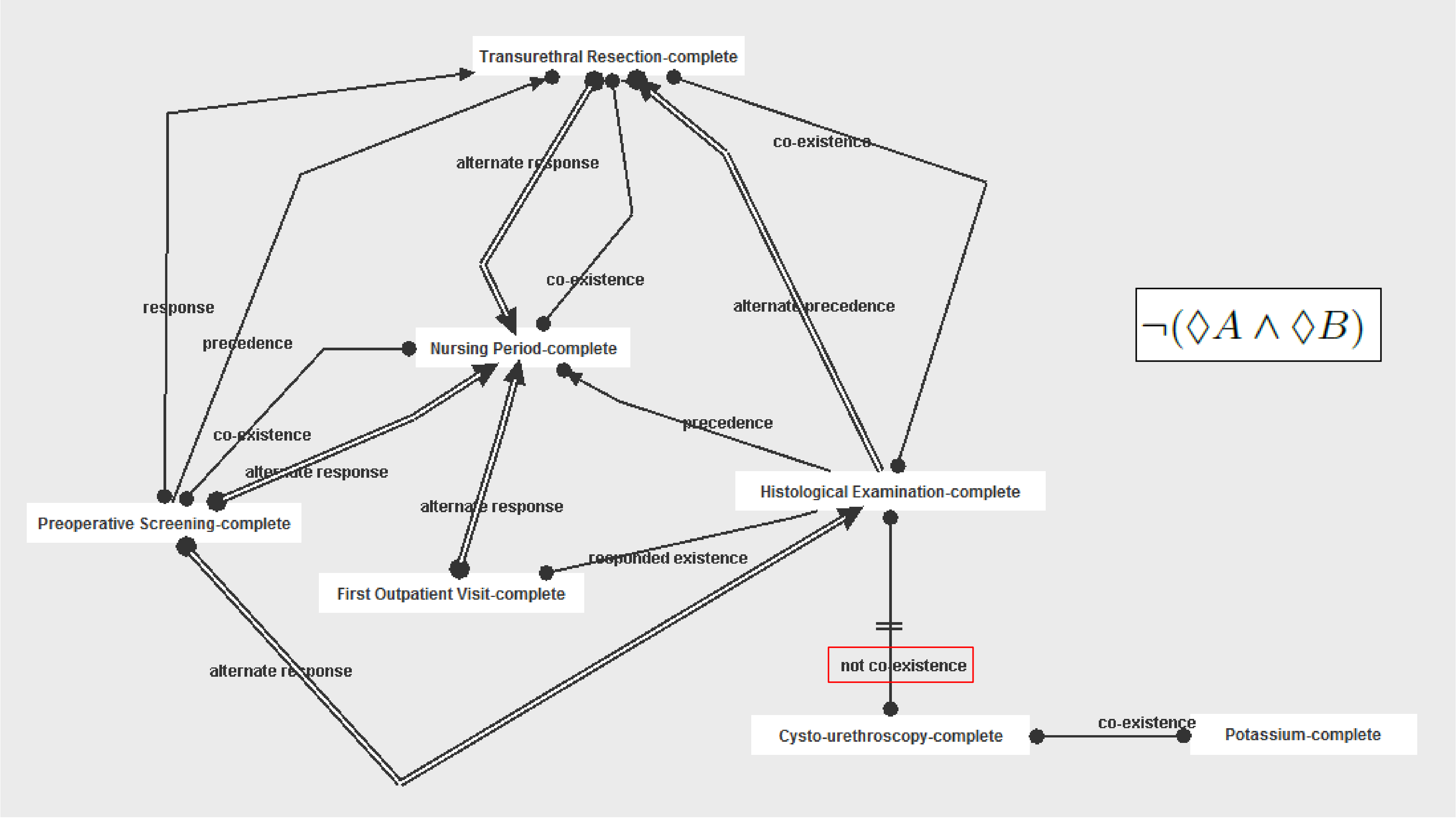
$$(\neg B \; U A) \vee \Box(\neg B)$$

An Example of DECLARE Model



$$\Diamond A \Leftrightarrow \Diamond B$$

An Example of DECLARE Model



$$\neg(\Diamond A \wedge \Diamond B)$$

Declarative Process Mining in ProM

- Declare Maps Miner
- Declare Analyzer
- Declare Replayer
- Declare Diagnoser
  - and many others….for a complete list, check:

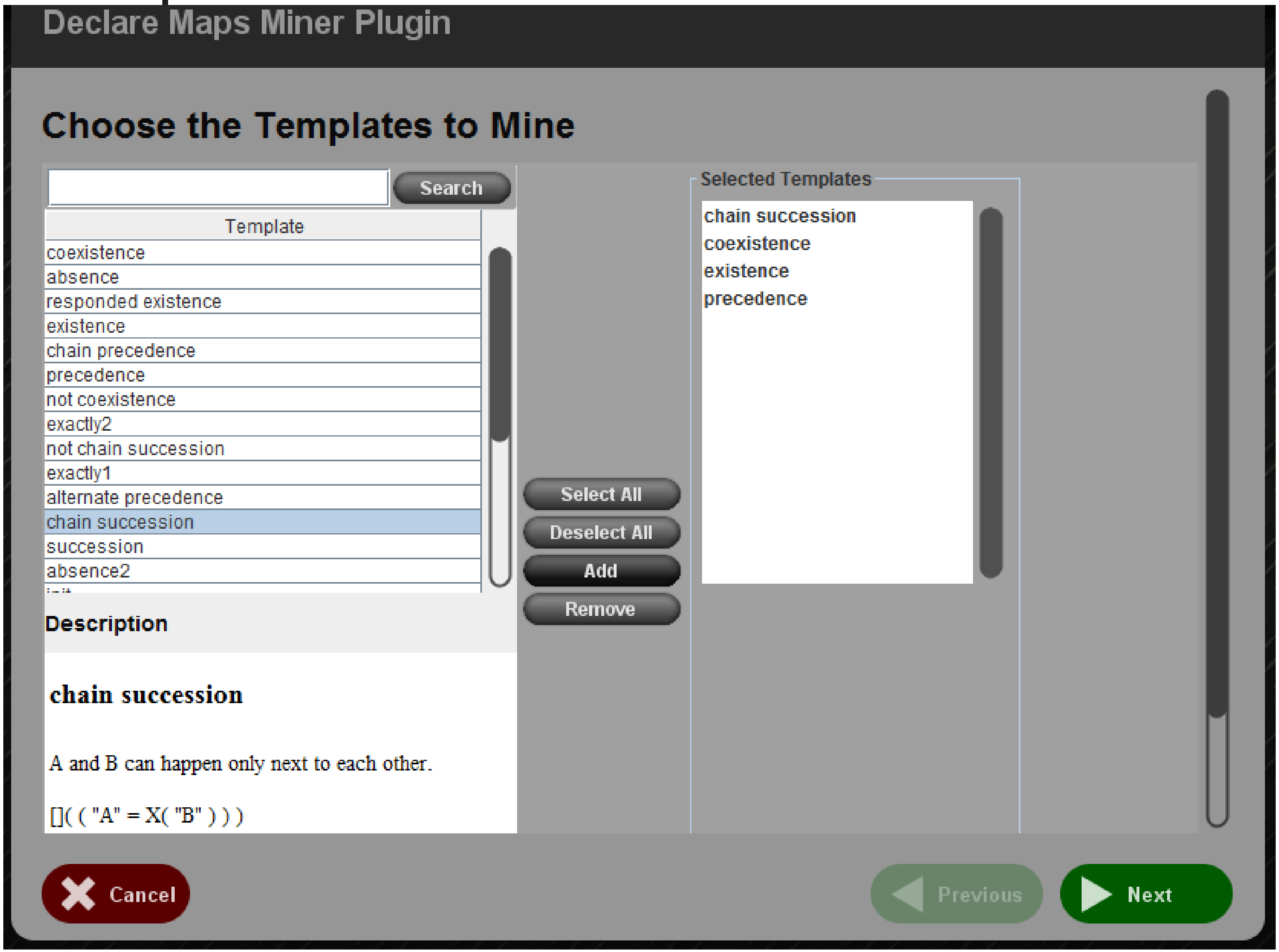
Fabrizio Maria Maggi
Declarative Process Mining with the Declare Component of ProM
12th International Conference on Business Process Management, BPM 2014

Declare Maps Miner /1

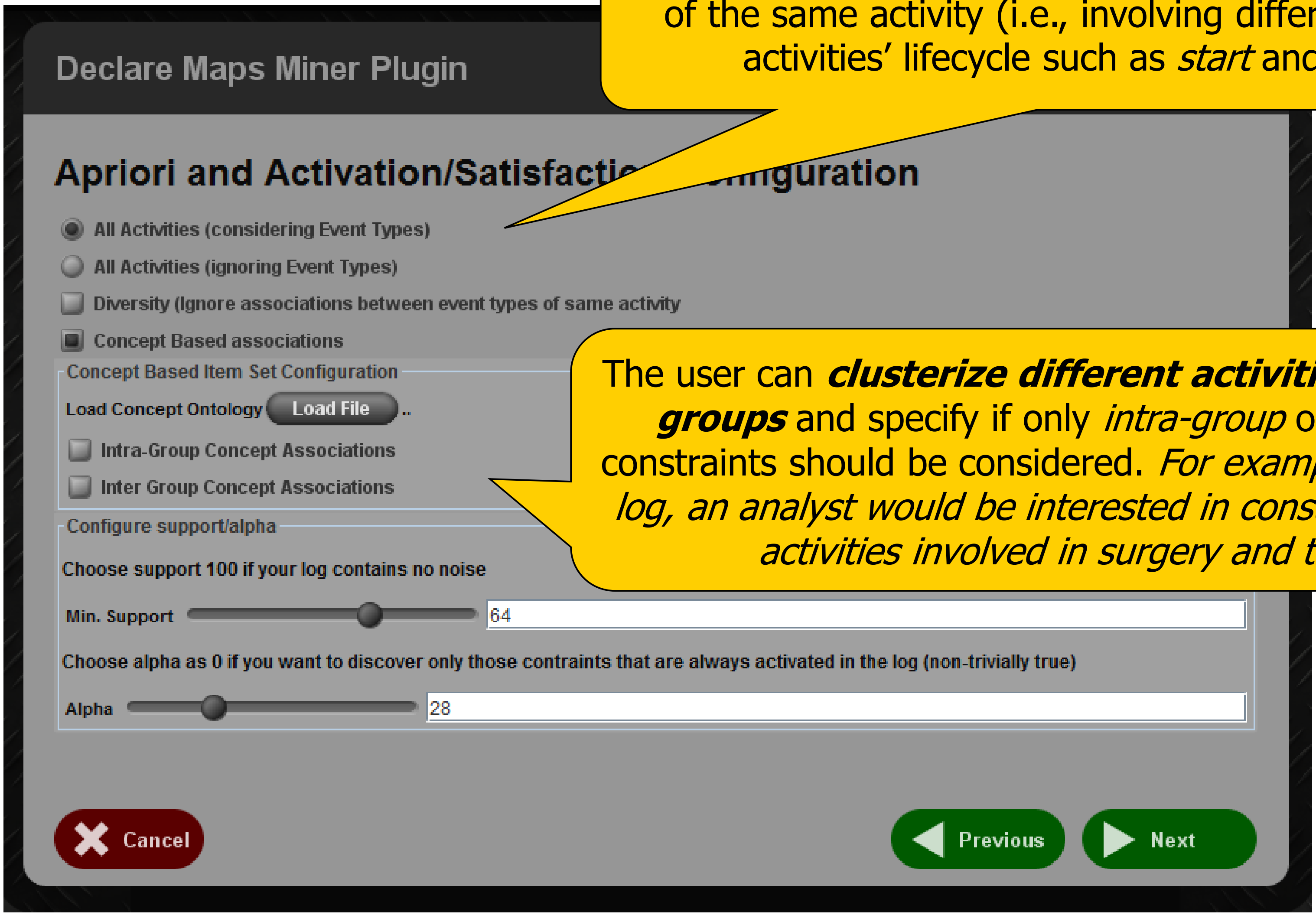
- The **Declare Maps Miner** allows to generate from scratch a set of DECLARE constraints representing the actual behavior of a process as recorded in an event log.

- The user selects from a list of DECLARE templates the ones to be used for the discovery task.
  - The mined model will contain **only constraints** that are instantiations of the selected templates.

Declare Maps Miner /2



Declare Maps Miner /3

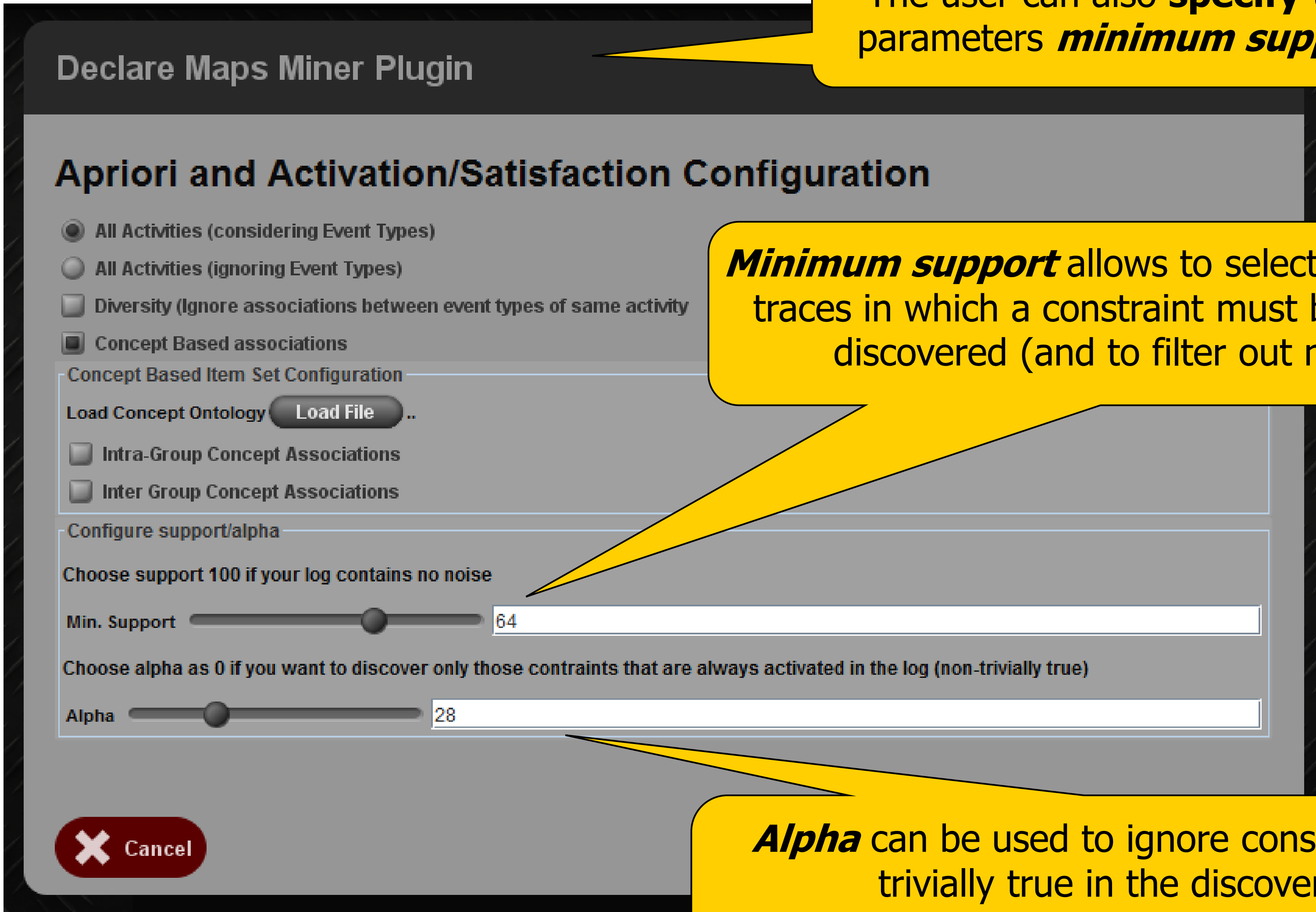


The user can ***ignore constraints between event types*** of the same activity (i.e., involving different parts of the activities' lifecycle such as *start* and *complete*).

The user can ***clusterize different activities in different groups*** and specify if only *intra-group* or *inter-group* constraints should be considered. *For example, in a hospital log, an analyst would be interested in constraints between activities involved in surgery and therapy.*

Declare Maps Miner /4

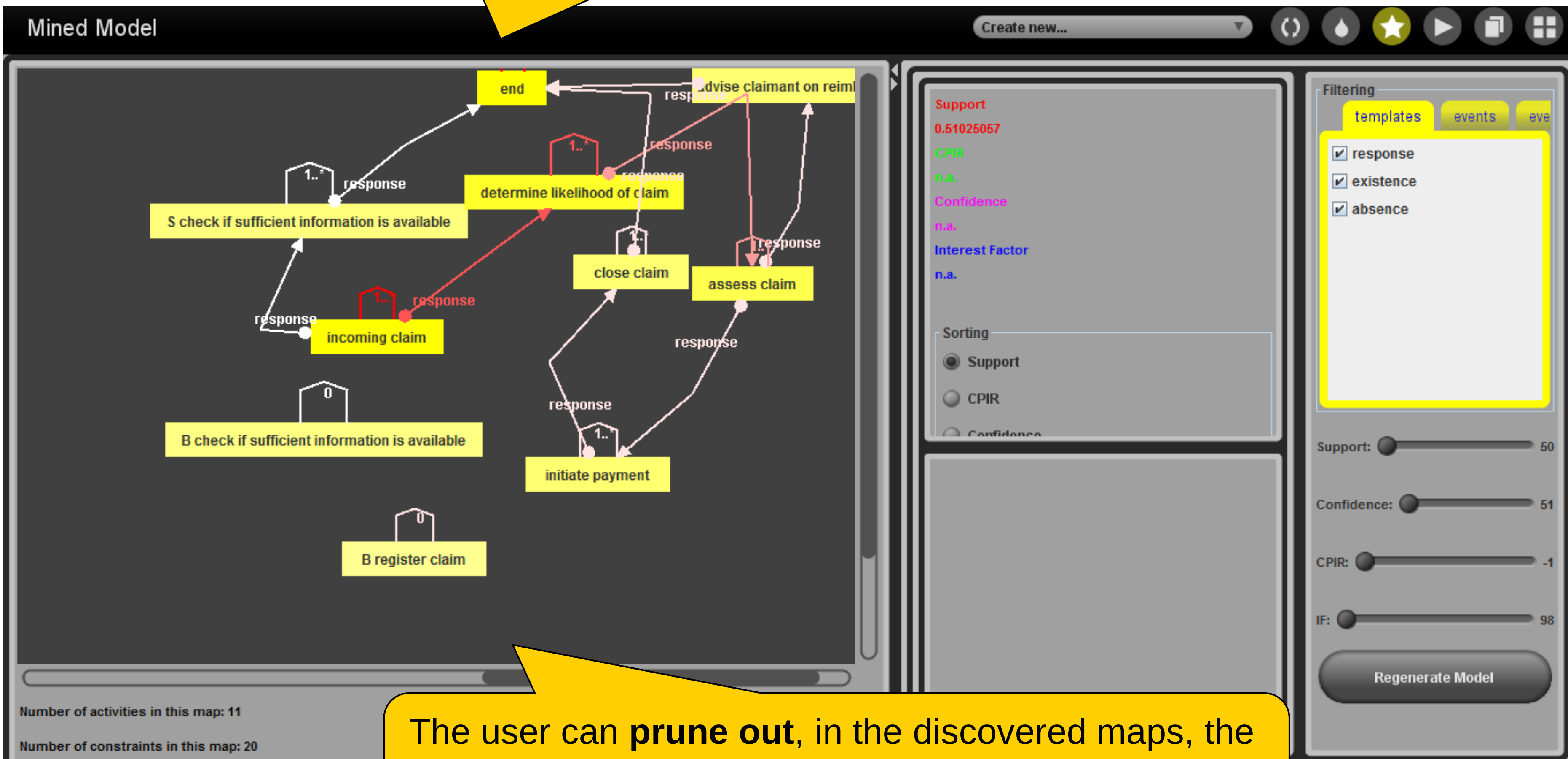
The user can also **specify thresholds** for parameters ***minimum support*** *and* ***alpha***.



Minimum support allows to select the percentage of traces in which a constraint must be satisfied to be discovered (and to filter out noisy traces).

Alpha can be used to ignore constraints that are trivially true in the discovery task.
For example, constraint response(A,B) is trivially true in process instances in which A does not occur at all.

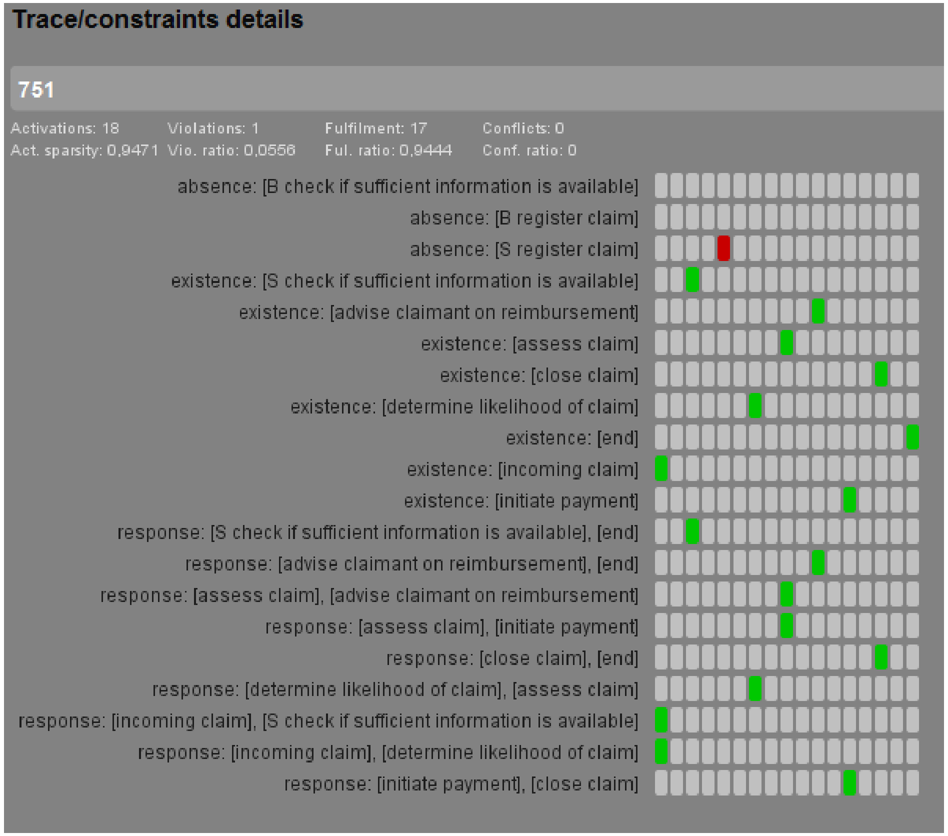
The discovery results are presented to the user as ***interactive maps***. Activities are colored based on their frequency (from **white** indicating low frequency to **yellow** indicating high frequency).



The user can **prune out**, in the discovered maps, the constraints that are less interesting, redundant or deriving from noise in the log.

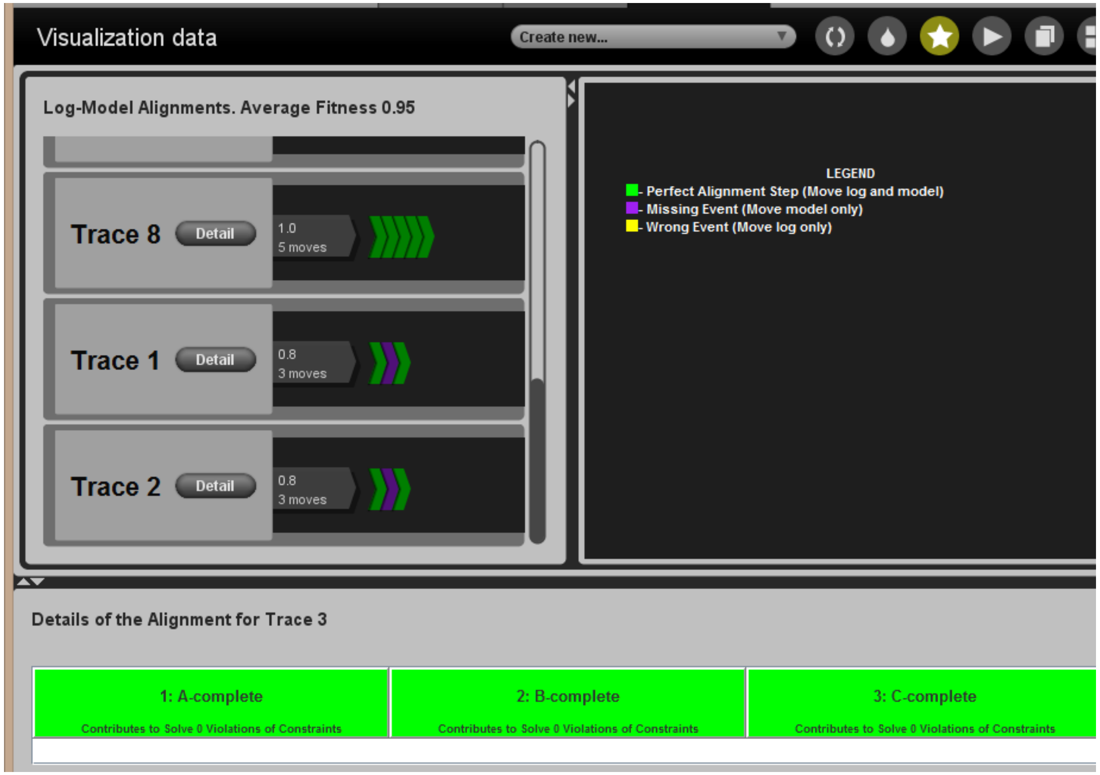
Declare Analyzer

- Through the **Declare Analyzer** the user can ***pinpoint*** where the process execution ***deviates*** from the reference DECLARE model.
- The ***degree of conformance*** of the process behavior can be quantified through several metrics, e.g., fulllment ratio and violation ratio.



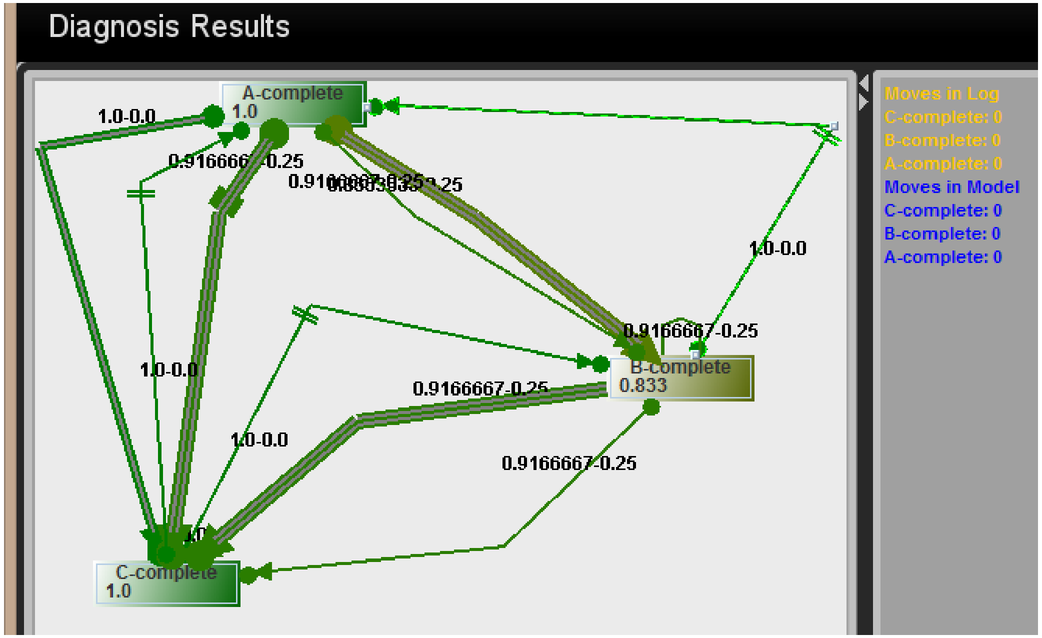
Declare Replayer

- The **Declare Replayer** generates a set of ***alignments*** between the log and the reference DECLARE model, i.e., information about what must be changed in the log traces to make them perfectly compliant with the model.



Declare Diagnoser

- The **Declare Diagnoser** projects the results obtained through the Declare Replayer onto the reference model.
- This projection produces a map in which the ***critical activities/constraints*** of the reference model are **highlighted**.



- Activities are colored from red to green according to the number of moves they are involved in, i.e., according to how many times they were in the wrong place in the log or missing when required.
- Constraints are colored from red to green based on the number of moves that are needed to make the log compliant to them.