Documentation of the ProM plugin

Uma
an Unfolding-based Model Analyzer

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http://www.processmining.org/

Uma implements techniques for analyzing and simplifying process models in ProM. The techniques build on the theory of **unfoldings of process models** and **McMillan prefixes** to analyze the behavior of process models in a compact, symbolic representation.

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1 Plugin: Analyze Model

This plugin allows to analyze behavioral properties of Petri net models. While it is easy to use, understanding the analysis results requires a little bit of knowledge on Petri nets and their behavior.

The plugin is called **Analyze Model Using Uma** and takes as input a Petri net.

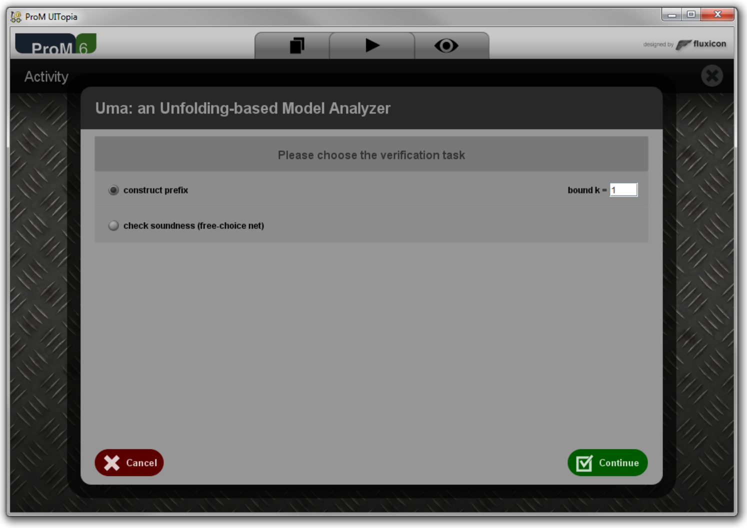
1.1 Requirements on the input

Each transition of the Petri net must have a pre-place (i.e., an arc from a place to the transition), and a post-place (i.e., an arc from the transition to a place). The plugin will not run if the model does not satisfy this requirement.

1.2 Running the plugin

Select a Petri net and the plugin **Analyze Model Using Uma** from the plugin list. The plugin has several options as shown in Figure 1.

construct prefix. Constructs the so called McMillan prefix of the Petri net, a tree-like structure representing the entire behavior of the net in a compact form (similar to a state space) while representing concurrency explicitly rather than by interleaving. The computed prefix is returned as a result and can be inspected as shown in Figure 2. It allows a system modeler particulary to understand which behavior can occur according to the model, for instance which transitions can occur.



Uma: an Unfolding-based Model Analyzer

Please choose the verification task

[✓ construct prefix] bound k = 1

check soundness (free-choice net)

Figure 1: **Analyze Model Using Uma**: Plugin options.

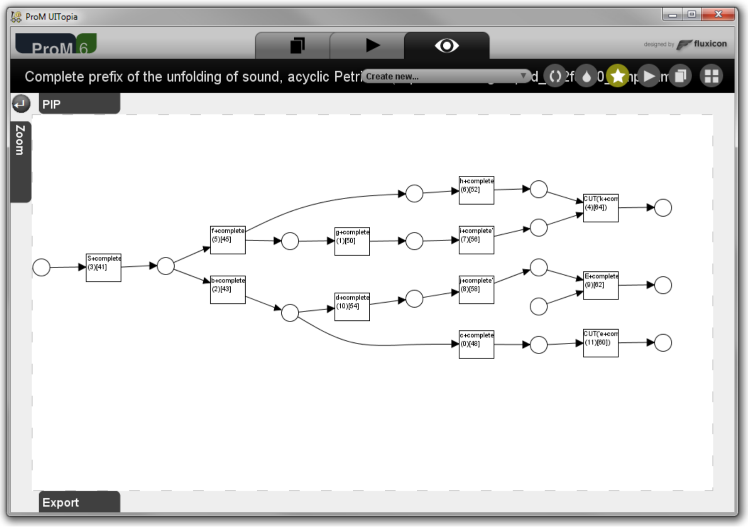


Figure 2: Unfolding of a process model.

The **parameter** k is used to ensure termination of the plugin in case the Petri net is unbounded. The plugin will stop when reaching a marking where a place contains more than k tokens. Default is $k = 1$.

check soundness. Checks sounds of a free-choice Petri net. If the net is sound, a corresponding result is shown. If the net is unsound, a counter-example is returned showing the behavior that leads to a violation of soundness which is in a free-choice net either a deadlock or an unsafe marking. Figure 3 shows such a counter example. It currently needs expert knowledge to interpret the counter example and identify the problem.

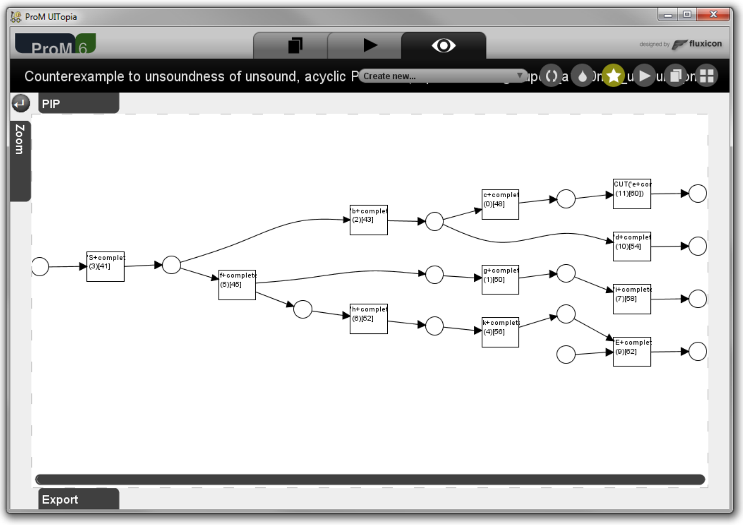


Figure 3: Counter-example showing unsoundness of a process model.

2 Plugin: Simplify Mined Model

This plugin allows to structurally simplify a process obtained from a process mining algorithm while preserving that the model can replay the entire log. The standard situation where this plugin may prove useful is when the model that was discovered from a given log shows complex control-flow structures as illustrated in Figure 4. The plugin to simplify such models works on Petri net models and requires *no expert knowledge* to be used.

The plugin is called **Simplify Mined Model Using Uma** and takes as input a log and a Petri net that was discovered from this log.

2.1 Requirements on the input

The plugin assumes that the Petri net was discovered from the provided log and that the Petri net can replay the entire log, i.e., that the model has fitness 1. Such models are obtained for instance using the **ILP Miner** or the **Transition System Miner**.

In case the Petri net cannot replay the entire log, the simplified model returned by the plugin will also cover only the behavior that could be replayed on the Petri net. In the worst case, the returned net may be empty.

The plugin assumes that the Petri net has no arc weights or multiple arcs. In case of arc weights or multiple arcs, the returned results are unpredictable.

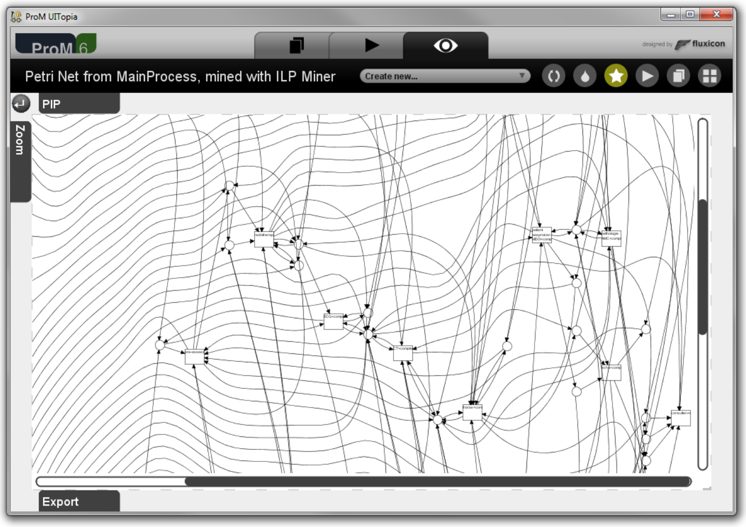


Figure 4: **Simplify Mined Model**: typical mined process model with complex control flow structures.

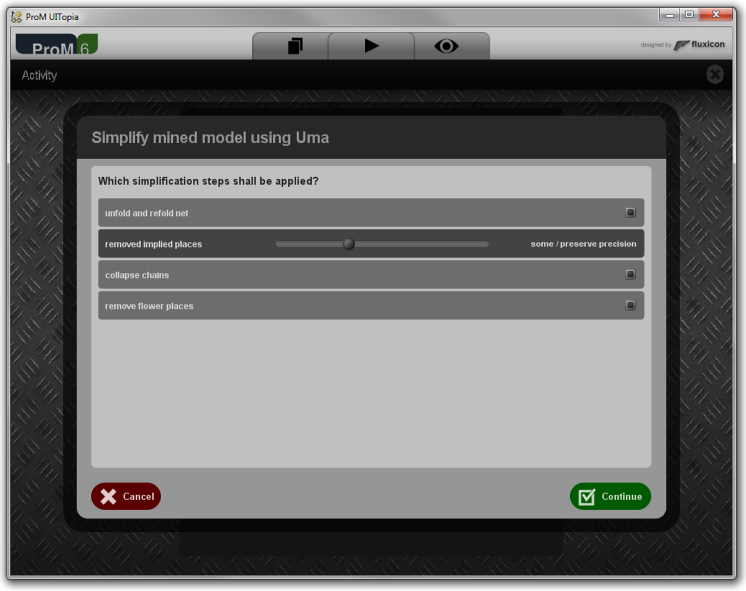
2.2 Running the plugin

Select a Petri net and the log from which the Petri net was discovered and and the plugin **Simplify Mined Model Using Uma** from the plugin list. The plugin implements a series of processing steps to simplify the given model. Each step provides a different kind of simplification. You may choose which simplification steps are run by the plugin using the configuration panel shown in Figure 5.

unfold and refold net Unfold the process model the unfolding (similar to an execution tree) that represents exactly the behavior described in the log (up to different interleaving of concurrent transitions), and then refold the unfolded model. This step slightly simplifies the model and reduces generalization introduced by the mining algorithm.

remove implied places Remove places from the net which do not contribute to restrict occurrences of transitions, i.e., where the net without the place has the same behavior as the net with the place (regarding the behavior in the log). This step allows to significantly simplify the model. However, simplification has to be traded for *precision*, that is, how much additional behavior the net will allow for compared to the log. This trade-off can be configured:

- **off** No place is removed.
- **some / preserve precision** Remove only places that are implied wrt. the complete behavior of the model. The resulting model may still be complex, but it is guaranteed to show the same runs as before.



Simplify mined model using Uma

Which simplification steps shall be applied?

unfold and refold net

removed implied places — some / preserve precision

collapse chains

remove flower places

Figure 5: **Simplify Mined Model**: plugin options.

- **more / preserve log causality** Remove only places that are implied wrt. the behavior seen in the log. The resulting model is less complex and it still exhibits the causal relations identified from the log.
- **most / preserve connectivity** Remove all places that in some context represent an implied causal dependency, but ensure that the net remains connected. The resulting model is significantly simpler; however precision is lost to some degree. (default)

collapse chains Unfolding and refolding a net (first step) may introduce a chain of transitions labeled with the same action. This step collapses such chains into a loop, thus reducing the net's structure further while generalizing its behavior.

remove flower places In some cases, the mining algorithm introduces *flower places* from which many transitions consume tokens and immediately put the token back. Such places largely sequentialize the connected transitions while making the net structure very involved. In this step, flower places which are connected to more than 5% of the net transitions are removed. This step may significantly simplify the net structure while generalizing the behavior.

All simplification steps are switched on by default. Upon clicking **continue**, the plugin will apply the chosen simplification steps and return the simplified net. Figure 6 shows the result of applying all simplification steps on the model of Figure 4.

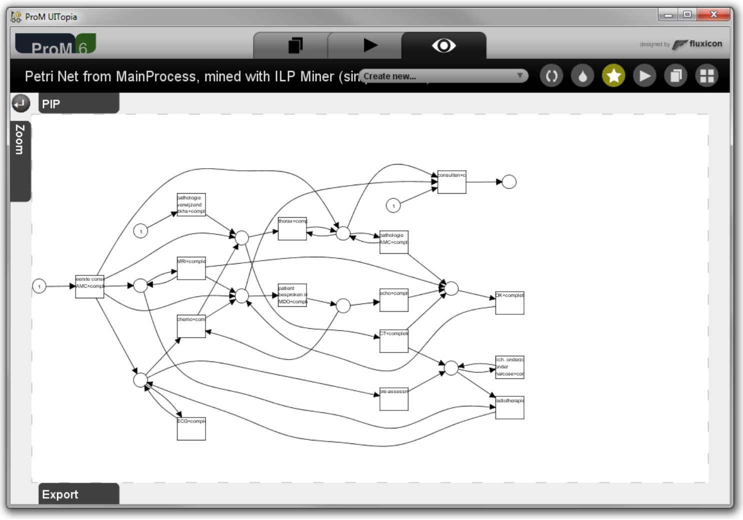


Figure 6: Model obtained by running the **Simplify Mined Model** plugin on the model of Figure 4.

3 Plugin: Repair Model

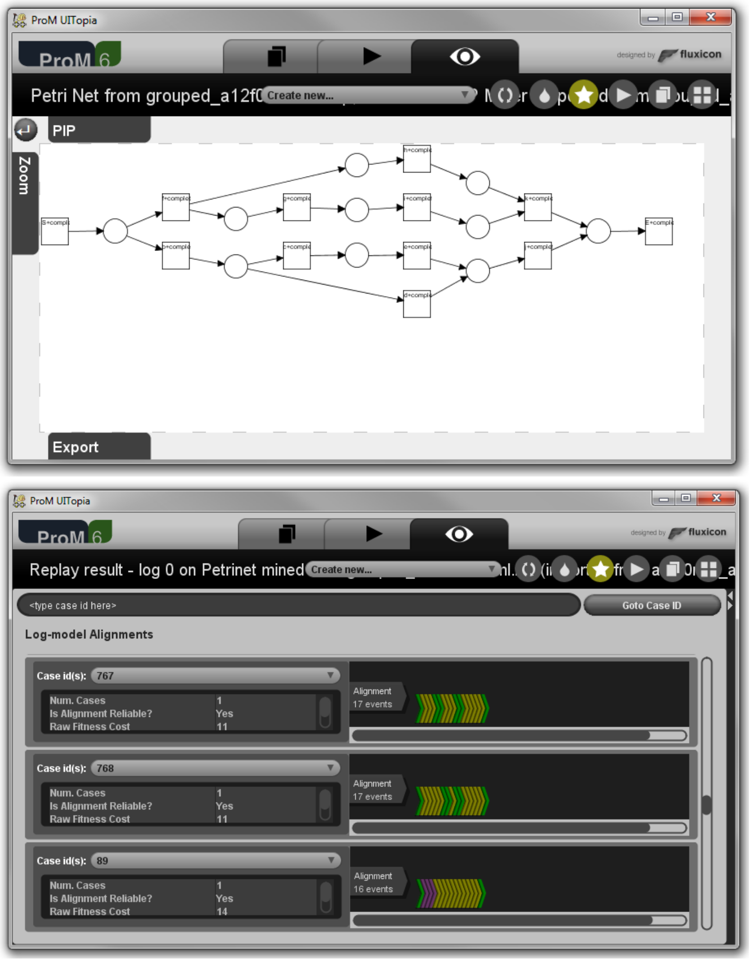
The **Repair Model** plugins allow to repair a given handmade process model (given as a Petri net) to reflect the reality of process executions that were observed in a log. The plugin can be applied in cases where a conformance check between model and log reveals misconformances as shown in Fig. 7.

3.1 Requirements on the input

The **Repair Model** plugins require that the given model has a clear notion of a final marking, that is, there is a particular marking that the process has to reach. Moreover, the plugin will deliver best results if the model is always able to reach the final marking. The **Repair Model** plugins will ask you to provide a final marking for your model if it is not specified yet.

3.2 Running the plugin

Select a Petri net and the log describing executions of the process in reality and run the plugin **Repair Model** from the plugin list. The plugin implements a series of processing steps to repair the given model. Each step provides a different kind of repair. You may choose which repair steps are run by the plugin using the configuration panel shown in Figure 8.



Log-model Alignments

Case id(s): 767

Num. Cases	1
Is Alignment Reliable?	Yes
Raw Fitness Cost	11

Alignment 17 events

Case id(s): 768

Num. Cases	1
Is Alignment Reliable?	Yes
Raw Fitness Cost	11

Alignment 17 events

Case id(s): 89

Num. Cases	1
Is Alignment Reliable?	Yes
Raw Fitness Cost	14

Alignment 16 events

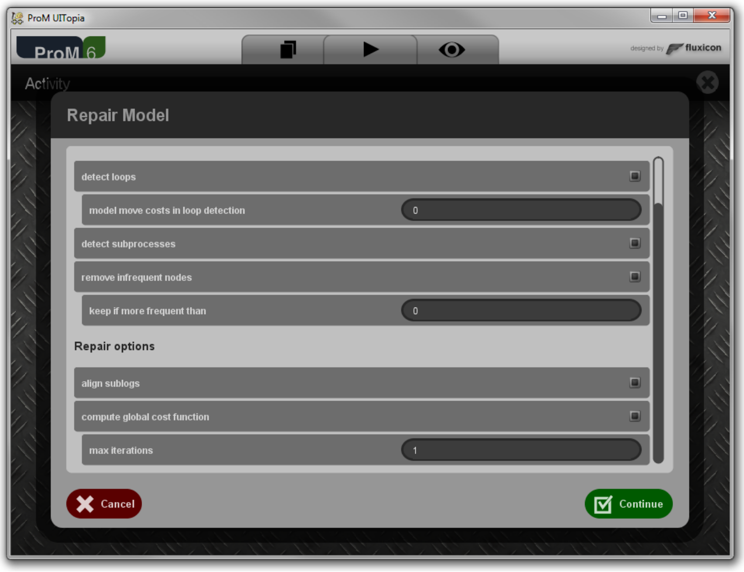
Figure 7: **Repair Model**: misconformances between log and model.

The main model repair steps are the following:

detect loops Find parts of the process model that, when extended with a loop-back transition yield a structured loop that can replay traces of the log that could not be replayed on the original model. The option **model move costs in loop detection** can be set to influence how loops are discovered. Generally, a value 0 yields best results but may have a poor performance. A value >0 may yield faster results but give a worse quality in the repaired model.

detect subprocesses For all remaining events that cannot be replayed on the original model, discover and add subprocesses that allow to replay these events.

remove infrequent nodes Find parts of the process model that are not needed to replay the log, and remove them. Setting **keep if more frequent than** to a



Repair Model

detect loops

model move costs in loop detection: 0

detect subprocesses

remove infrequent nodes

keep if more frequent than: 0

Repair options

align sublogs

compute global cost function

max iterations: 1

Figure 8: **Repair Model**: plugin options.

value > 0 will also remove parts of the model that are used infrequently. This way, parts of the model that describe noisy behavior can be filtered out.

In addition, each repair step can be configured using 2 parameters:

align sublogs Decomposes and groups sequences of events that cannot be replayed into sets of very similar sequences. This typically yields more but smaller, and better structured, subprocesses.

compute global cost function Misconformances between log and model are computed using a cost function. Enabling this option computes an improve cost function that yields better repairs (less changes to the model), at the price of additional computations. **Max iterations** defines how often the current cost function shall be improved to, we found 1 iteration to be sufficient in most cases.

Once the parameters are set, **ProM** will ask you to map transitions of the model to event classes. Then the **Repair Model** plugin will run the specified model repair steps. Figure 9 shows the model of Fig. 7 after repairs.

The individual steps of the **Repair Model** plugin can be controlled in a more detailed way using the separate plugins for detecting loops, detecting subprocesses, and removing infrequently used parts. Each of these plugins takes as input model, log, and an *alignment* between model and log as it is returned by the conformance checker. The repair will always be conducted with respect to the alignment, and choosing a particular cost function, or a particular

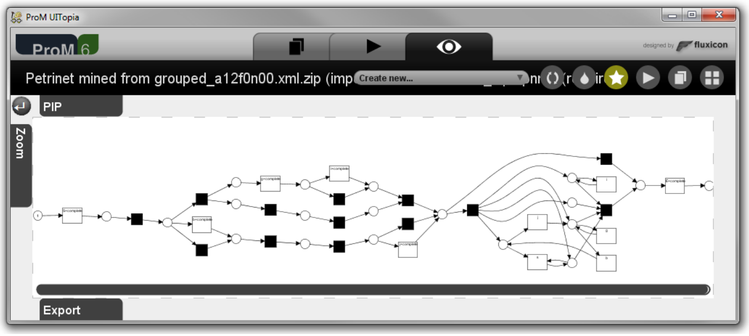


Figure 9: **Repair Model**: plugin options.

conformance checker, will yield a particular alignment, and hence, a particular kind of repair. Two plugins for computing alignments with global costs, and for computing alignments that improve the discovery of loops are provided by **Uma** as well.

4 Technical Background and References

Further information on the techniques implemented in **Uma** can be found in the following books and articles.

General information about the technique of unfoldings and McMillan prefixes of Petri nets can be found in the following book:

> J. Esparza and K. Heljanko. **Unfoldings - A Partial-Order Approach to Model Checking.** Springer-Verlag, 2008.

The technique for simplifying mined process models is described in the following article:

> Dirk Fahland and Wil M.P. van der Aalst. **Simplifying Mined Process Models: An Approach Based on Unfoldings.** In Proceedings of the 9th International Conference on Business Process Management, BPM 2011, volume 6896 of Lecture Notes in Computer Science, pages 362Ű378. Springer-Verlag, 2011

The technique for repairing process models is described in the following article:

> Dirk Fahland and Wil M.P. van der Aalst. **Repairing process models to reflect reality.** In Business Process Management 2012, volume 7481 of Lecture Notes in Computer Science, pages 229Ű245. Springer, 2012.

The source code of this plugin is available from the ProM website `http://www.processmining.org/` under the GNU Affero General Public License Version 3 or later.