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# Methods for Business Process Simulation Based on Petri Nets

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***Abstract*—**The Petri nets are the first standard for business process modeling. Most probably, it is one of the core reasons why all new standards created afterwards have to be so reformed as to reach the stage of mapping the new standard onto Petri nets.

The paper presents a business process repository based on a universal database. The repository provides the possibility the data about a given process to be stored in three different ways. Business process repository is developed with regard to the reformation of a given model to a Petri net in order to be easily simulated.

Two different techniques for business process simulation based on Petri nets - Yasper and Woflan are discussed. Their advantages and drawbacks are outlined. The way of simulating business process models, stored in the Business process repository is shown.

***Keywords*—**Business process repository, Petri nets, Simulation, Woflan, Yasper.

## I. Introduction

BUSINESS process modeling is a fast developing discipline directed to business analysis with the aim to obtain different specific concepts of a given enterprise. The concepts are mutually complementary helping the complete perception of a complex system by outlining every significant element. They are represented by models, which describe the processes and services executed within a company. All this appears to be the main reason for creating lots of languages and methods, which are used for business models description. One of the pioneering methods applied in business process modeling is Petri net technology.

Petri nets offer a graphical representation of stepwise processes including choice, iteration and concurrent execution. They are distinguished with an exact mathematical definition of their execution semantics, and a well-developed mathematical theory for process analysis. Petri nets are one of the known techniques for describing business processes in a formal and abstract way [8], [9]. There are four general approaches to Petri net analysis:

1. Reachability Analysis, involves the enumeration of all reachable markings, but it suffers from the state-space explosion issue;
2. The Matrix Equation Approach, in many cases it is applicable only to special subclasses of Petri nets or special situations;
3. Invariant Analysis, determines sets of places or transitions with special features, as token conservation or cyclical behavior;
4. Simulation, discrete-event simulation is an option to check the system properties.

The Petri nets are the first standard for business process modeling. Most probably, it is one of the core reasons why all new standards created afterwards have to be so reformed as to reach the stage of mapping the new standard onto Petri nets.

The team involved in the research found the solution by creating Business Process Repository.

Business Process Repository is the central location for storing information concerning how an enterprise operates. The administration of a business process repository includes activities such as storing, managing, and changing the knowledge about the processes of an enterprise. It is responsible for: creating a repository structure; defining and maintaining the procedures, so as to ensure that all changes are controlled, validated and approved; mapping processes to applications and data; providing the suitable infrastructure for enabling the effective and consistent use of the models stored in the repository.

The business process repository created and described in the [1], [2] is represented through a universal database. The repository provides the possibility the data about a given process to be stored in three different ways:

- The first one is focused on the storage of business process characteristics such as number, description, responsible units, input data, output data, resources, and others. These features can be extended and supplemented;
- The second description allows maintaining the hierarchical structure of a process. The relationships between processes and their sub-processes are represented by showing the parent process and the relevant child processes. In these dependencies a single process may appear both as a complex process with sub-processes, and as a sub-process of a process from a higher level;
- The third presentation deals with the information about the graph structure of the process. Events, generated in result of process execution and used to start other processes, provide information that allows constructing the sequence (or sequences) of the sub-processes of a particular process.

The business process repository proposes the main functions of process maintenance, as well as a high degree of business process templates' reuse. Business process repository is developed with regard to the reformation of a given model to a Petri net. The method of model's reformation into a Petri

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net is shown in [3]. After a given model is represented as a Petri net, then it can be easily simulated.

This study investigates the simulation as approach to Petri nets analysis. Business process simulation with Petri net tools is an option to represent the properties of a system. The core idea is to use a suitable algorithm for execution with the aim to reveal the presence of undesirable properties, but it cannot show and prove the correctness of the model in general case. Nevertheless, Petri net-based simulation is a convenient method for checking the desirable properties of a business process and/or system. The execution algorithm to run the Petri net includes the following steps:

1. Initialization: define the initial marking and the set of all enabled transitions in the marking;
2. If the number of preset simulation steps or certain stopping criteria is met, stop. Otherwise, if there is no transition enabled, report a deadlock marking and either stop or go to Step 1;
3. Randomly pick a transition to fire. Remove the same number of tokens from each of its input places as the number of arcs from that place to the transition and deposit the same number of tokens to each of its output places as the number of arcs from the transition to that place.
4. Remove all disabled transitions from the enabled transition set, and add all newly enabled ones to the enabled transition set. Go to Step 2.

The algorithm has been initially suggested for business process simulation based on Petri nets tools. Over the years, the algorithm underwent a number of changes. The changes originate from the fact that Petri nets have many extensions. The algorithm itself is being extended and most frequently used with the following modification: following-up the time required for execution of the whole process as well as the time needed for passing the transitions.

Nowadays, the usage of such algorithm is obviously helpful, as it allows to pre-detect a number of deadlocks, which may prevent the occurrence of serious errors like an incorrectly invented technological process as part of a series production that may cause dramatic problems to the company, additional work, legal consequences, irritated client, mismanagement and depressed employees. Therefore, it is of primary importance to check the correctness of a business process before starting it. In that context, the paper presents the following Petri net extensions for business process simulation:

1. Yasper
2. Woflan

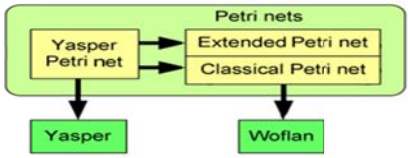


Fig. 1 Tools for analysis and transformation of business processes

## II. Yasper

Yasper is a tool for modeling, analyzing and simulating automated business processes (workflow). Yasper is based on Petri net technology. In Yasper it is possible to model and animate random places and transitions within a net by keeping the following features:

- Hierarchy – a net can be divided into subnets;
- Choice (XOR) – a symbol for denoting alternative paths for execution;
- Roles – users or resources, which can be assigned to transitions. In the process of animation the roles are represented with transitions that can be executed;
- Arcs deletion – used when testing empty places;
- Data stores – places, which always have a single token. They are used for representing databases;
- Time, cost and probability are in the basis of stochastic simulation. Transitions can be timed or can be executed beyond the time interval. Transition time may:
  - be fixed;
  - have an assigned average value with a standard deviation;
  - be unavailable.

Processing cost of transition is an analogous case. It can be fixed, variable per time.

- Identities case, segregation and aggregation case – used for manual and automatic simulation of processes;
- Automatic simulation – provides records for correct ending of cases and statistics reports for execution of the workflow [4].

## III. Woflan

Woflan (Workflow Analyzer) is a software tool for analyzing the reliability of a workflow in the terms of Petri nets by verification of the process correctness and issuance of reports on encountered problems.

Woflan is developed by members of the SMIS group in the department of Mathematics and Computer Science at Eindhoven University of Technology [10].

Woflan is composed of three main parts:

1. Parser – analyzes workflow definitions specified in terms of Petri nets. It is assumed that a Petri net has the following structure: one input place corresponding to the entry point of the workflow and one output place corresponding to the workflow exit point. The parser reads the Petri net from the input file and builds up the data structure of each workflow that has to be analyzed. If the Petri net does not satisfy the specified requirements, Woflan will warn the user.
2. Analysis routines – the data structure built up by the parser is used for different kinds of analysis. Woflan will warn for incorrect usage of specified constructs and it can detect incorrectness in tokens' application.
3. User interface – built up by using XVT. Woflan techniques enable multiple workflows analysis at the same time, as each workflow definition corresponds to a separate window.

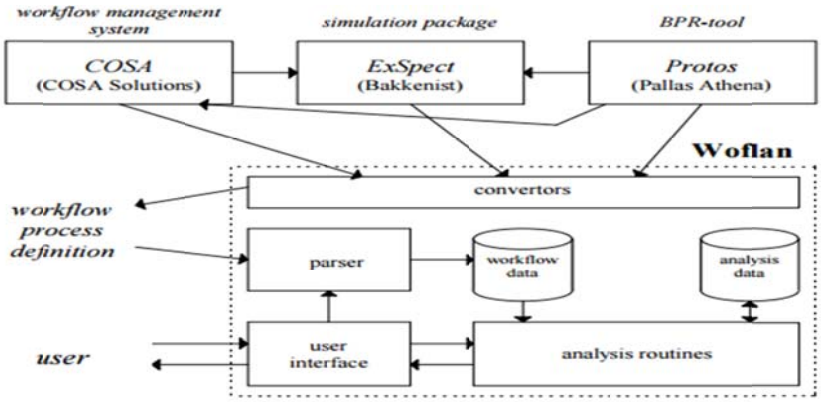


Fig. 2 Architecture of Woflan

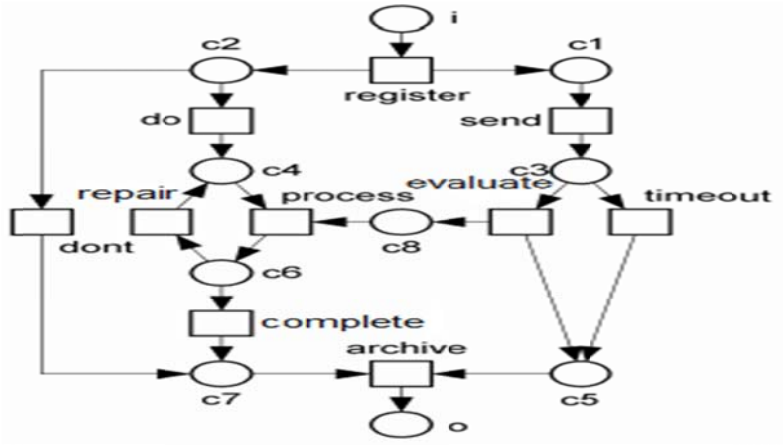


Fig. 3 Business process representation with a Petri net

Woflan is a tool for verifying the workflow correctness. It uses numerous techniques for detecting potential errors during a workflow development. On one hand, Woflan uses modern techniques for business process analysis, and on the other hand, it is clear that Woflan needs to interface with other tools like COSA and Protos for modeling and analyzing workflows.

To list the advantages and disadvantages of the two methods for business process simulation in the terms of Petri nets, we shall focus one and the same process. Fig. 3 shows a business process in the terms of a classical Petri net.

The business process represented in Fig. 3 shall be considered firstly in the terms of Woflan. For analyzing the process in accordance with Woflan it is necessary to model it using COSA, Staffware and Protos.

COSA (COSA Solutions) [5] is one of the leading workflow management systems in the Netherlands. COSA allows for the modeling of complex workflow processes. The modeling language of COSA is based on Petri nets. A disadvantage of COSA is that it does not support verifications. Woflan can analyze any workflow process definition constructed by using CONE. CONE (COSA Network Editor) is the design tool of the COSA system. Fig. 4 shows the same workflow definition as that in Fig.3. In Fig. 4, the process is designed with the help of CONE tools.

Woflan can import workflow definitions from Staffware [7]. Staffware is widespread workflow management systems in the world. It uses a proprietary graphical input language for specifying business process definitions. Nevertheless, Woflan can analyze some useful properties of business process definitions made with Staffware.

Woflan can be used to realize the process definitions which are made with Protos. Protos [6] is a Business Process Reengineering tool. It can be used to (re)design and analyze workflows.

The result of the foregoing business process simulation is represented with a number of dialog windows within 14 steps. Each window is aimed to show all advantages and/or disadvantages of the process. The main disadvantage of the product is that it cannot generate a report to show the main disadvantages of the modeled business process within the frames of one dialog window.

The business process represented in Fig. 3 is now viewed in the terms of Yasper. The advantage of Yasper compared to Woflan is that using Yasper techniques it is possible to create a business process model, to edit the designed model and to start it manually or automatically.

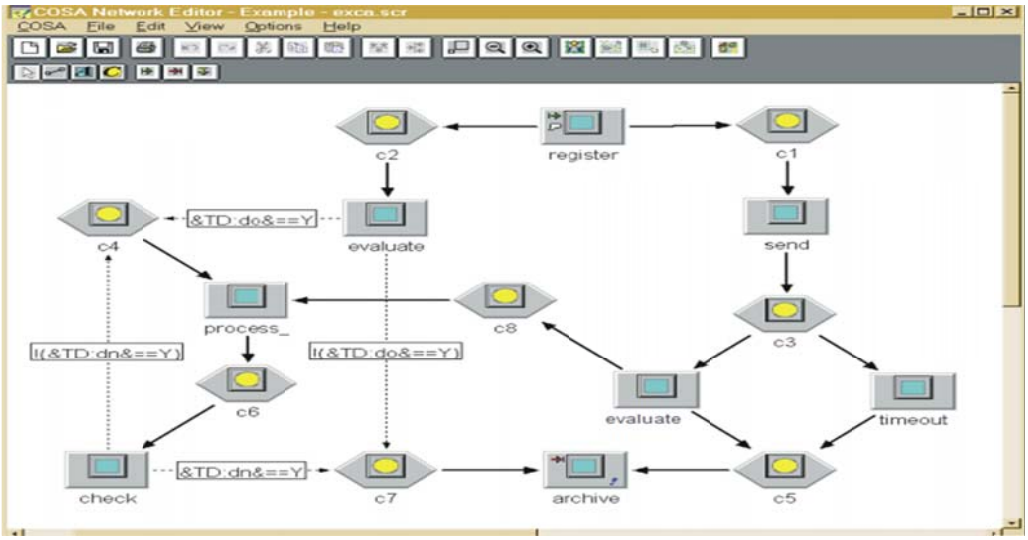


Fig. 4 The business process of Fig. 3 designed with COSA

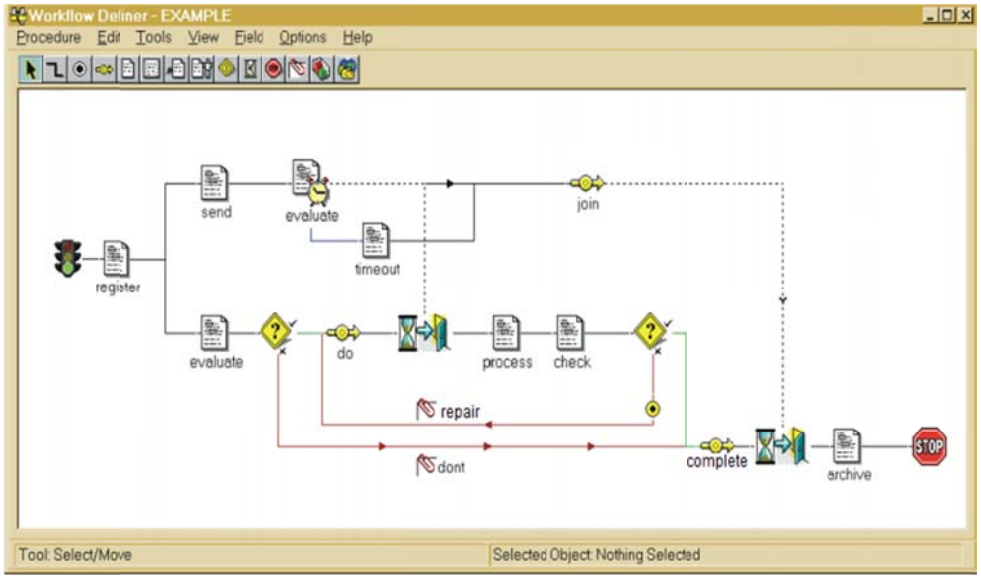


Fig. 5 The business process of Fig. 3 designed with Staffware

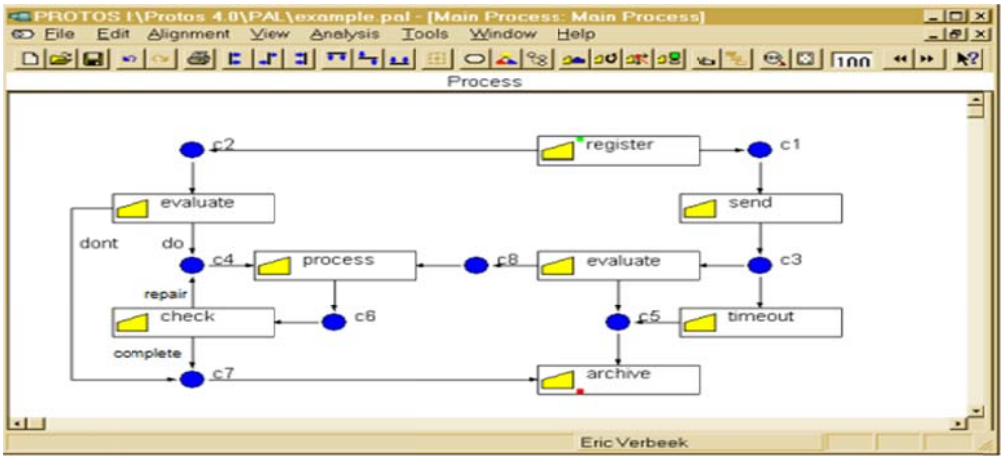


Fig. 6 The business process of Fig. 3 designed with Protos

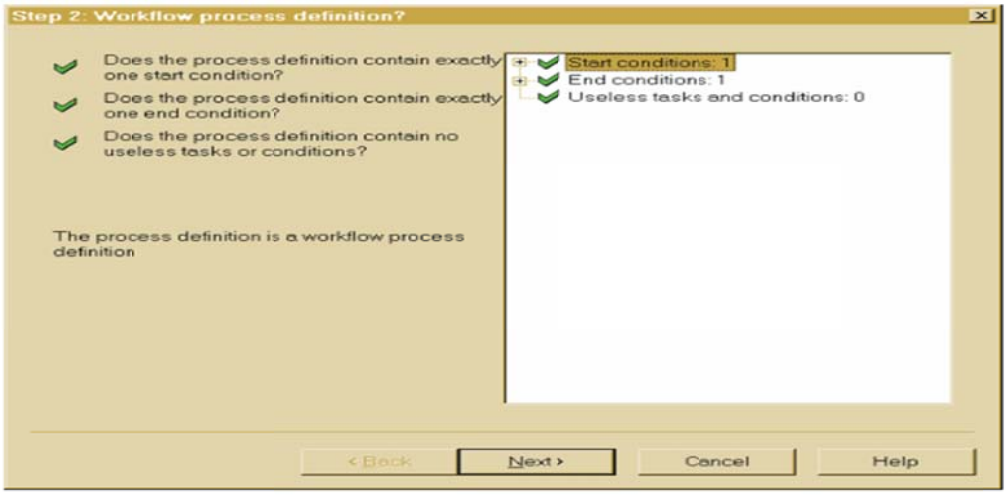


Fig. 7 One of the 14 steps analyzing the results of the business process of Fig. 3 designed with Woflan

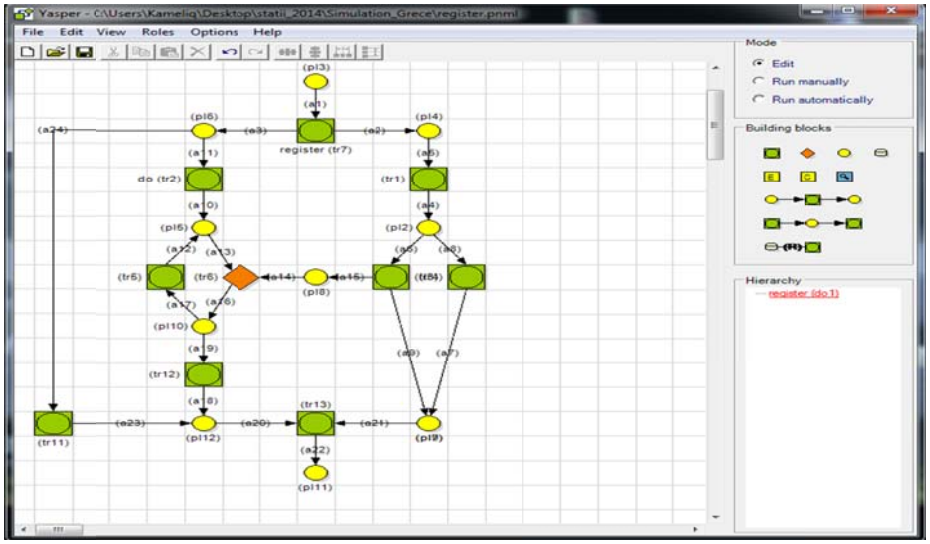


Fig. 8 The business process of Fig. 3 designed with Yasper

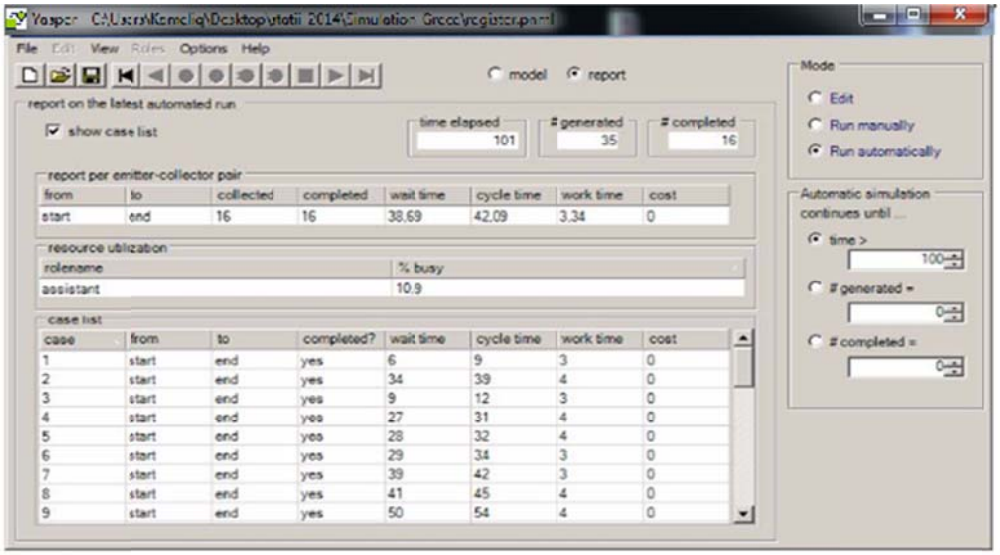


Fig. 9 Report the results of the business process of Fig. 3 designed with Yasper

## IV. Conclusion

Simulation is one of the most important approaches to analyses and improvements of workflow definitions. Two different Petri net extensions for business processes simulation have been presented in this paper. These simulation methods are based on colored Petri nets. The main advantage of Yasper is that there is no need:

- to get acquainted with the theory and semantics of tools as COSA, Staffware and Protos, and
- the result of the business process simulation to be represented within the frames of one dialog window. When a user is reviewing the model, Yasper allows switching regimes, e.g. from the regime of model to regime of report and vice versa.

The advantage of Yasper is that it allows simulating business processes that are modeled (created) in a different environment. The main requirement is models to be based on Petri nets.

Woflan and Yasper prove that the workflow market is a challenging application domain for Petri-net-based technology.

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